Environmental & Water Quality
Operational Studies

INSTRUCTION REPORT E-82-2

HANDBOOK OF ENVIRONMENTAL QUALITY MEASUREMENT AND ASSESSMENT: METHODS AND TECHNIQUES

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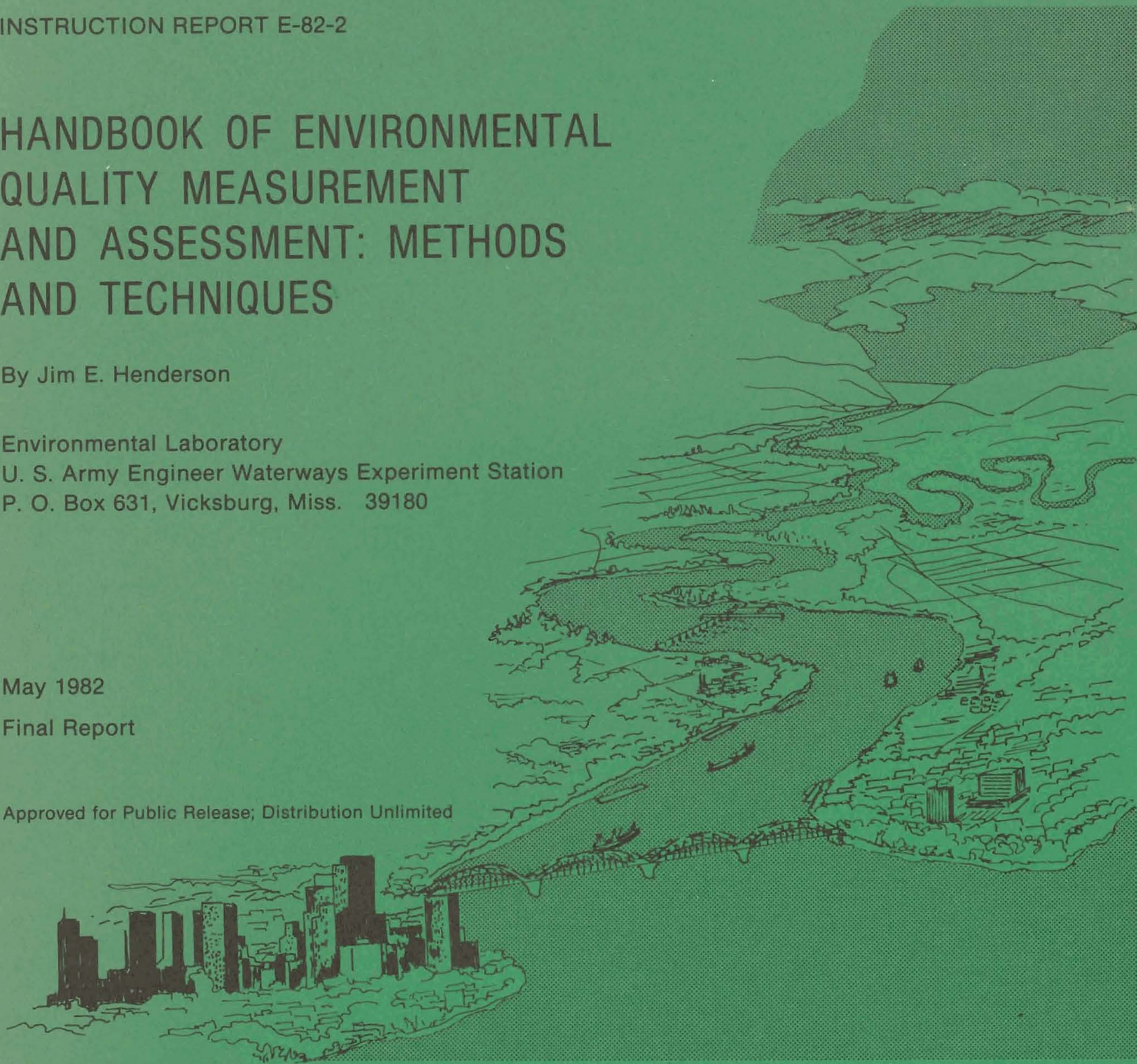

May 1982
Final Report

Prepared for Office, Chief of Engineers, U. S. Army
Washington, D. C. 20314

Under EWQOS Task IVA (Work Unit 31607)

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: Instruction Report E-82-2	2. GOVT ACCESSION NO.
	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): HANDBOOK OF ENVIRONMENTAL QUALITY MEASUREMENT AND ASSESSMENT: METHODS AND TECHNIQUES	5. TYPE OF REPORT & PERIOD COVERED: Final Report
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): Jim E. Henderson	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: U. S. Army Engineer Waterways Experiment Station Environmental Laboratory P. O. Box 631, Vicksburg, Miss. 39180	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: EWQOS Task IVA Work Unit 31607
11. CONTROLLING OFFICE NAME AND ADDRESS: Office, Chief of Engineers, U. S. Army Washington, D. C. 20314	12. REPORT DATE: May 1982
	13. NUMBER OF PAGES: 350
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Available from National Technical Information Services, 5825 Port Royal Road, Springfield, Va. 22151

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Guidance is provided for the selection and use of environmental analysis techniques for environmental quality planning and evaluation. Uses of generic types of environmental analysis methods (such as environmental impact matrices for environmental planning) are explained. Technique profiles are given to support planning steps, and four Performance Matrices are given to assist the user. One section contains measurement and evaluation techniques for use in Environmental Quality Evaluation Procedures with (a) technique profiles that

(Continued)

20. ABSTRACT (Continued)

describe methods, techniques, and procedures for characterizing ecological, cultural, and aesthetics and (b) Profile Characteristics Matrices. An extensive bibliography contains the references, reports, and citations also considered in preparing the handbook.

Preface

This report summarizes the results of a review and an evaluation of methodologies and techniques for environmental analysis to be used in the Corps of Engineers' multiobjective planning process. The review and evaluation were performed under the Environmental and Water Quality Operational Studies (EWQOS) Program, Work Unit IVA, at the Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station (WES). The EWQOS Program is sponsored by the Office, Chief of Engineers, and managed by WES.

The review and evaluation were conducted and the report was prepared by Mr. Jim E. Henderson. Significant contributions to the report were made by Ms. Sue E. Richardson, Dr. Stanley A. West, Dr. John A. Rorabacher, Mr. Mike McCoy, and Ms. Jerre Gibson, all formerly of WES; and Dr. Larry Canter, consultant to Work Unit IVA. This work was under the direct supervision of Mr. William J. Hansen, Chief, Resource Analysis Group, and under the general supervision of Dr. Conrad J. Kirby, Chief, Environmental Resources Division, and Dr. John Harrison, Chief, Environmental Laboratory. Dr. Jerome L. Mahloch was the EWQOS Program Manager.

The Commanders and Directors of the WES during this study were COL John L. Cannon, CE, COL Nelson P. Conover, CE, and COL Tilford C. Creel, CE. Technical Director was Mr. F. R. Brown.

This report should be cited as follows:

Henderson, Jim E. 1982. "Handbook of Environmental Quality Measurement and Assessment: Methods and Techniques," Instruction Report E-82-2, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

Contents

HANDBOOK OF ENVIRONMENTAL QUALITY MEASUREMENT AND ASSESSMENT: METHODS AND TECHNIQUES

Introduction

1. In fiscal year 1978, a review of methodologies to support and improve environmental analysis in Environmental Quality planning was initiated. Guidance from the Office, Chief of Engineers, and the field indicated that there was no need or desire for a single environmental planning methodology. Rather, there was a recognized need for multiple tools and techniques to address the different aspects of environmental planning.

2. During the period of the review, there were a number of policy changes affecting the review of methodologies. The most important changes were two publications in 1980 by the Water Resources Council: Principles and Standards for Water and Water Related Land Resources Planning* and Environmental Quality Evaluation Procedures.** Therefore, the review of methodologies was oriented to identifying (a) environmental analysis methods for the planning steps set out in Principles and Standards and (b) techniques for use in the Environmental Quality Evaluation Procedures.

3. The Principles and Standards (P&S) and Environmental Quality Evaluation Procedures (EQEP) provide broad procedural and policy guidance for Corps of Engineers environmental studies. While P&S and EQEP set forth the essential planning and evaluation process, they do not provide detailed technical procedures for the conduct of environmental analysis. To provide the field with technical procedures for environmental analysis, a review and an evaluation of state-of-the-art

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* Water Resources Council. 1980. "Principles and Standards for Water and Water Related Land Resources Planning - Level C; Final Rule," Code of Federal Regulations, 18CFR Part 711.

** Water Resources Council. 1980. "Environmental Quality Evaluation Procedures for Level C Water Resources Planning; Final Rule," Code of Federal Regulations, 18CFR Part 714.

methodologies and techniques for environmental analysis were undertaken and are reported herein.

Study Approach

4. The approach taken to identify techniques and methodologies incorporated input from the field in addition to a succession of literature searches. Input from the field was elicited through a 1979 workshop and the review of two Engineer Circulars (ECs). The workshop and comments to the ECs assisted in identifying problem areas in which there was a recognized need to identify additional techniques. The literature searches included the period 1960-1980 and covered a broad range of environmental planning considerations. Additional techniques were also identified through field contacts.

5. The rationale or criterion for selecting references that contain potentially useful techniques and methodologies was an evaluation of the relevancy and utility of a technique as demonstrated in published abstracts or other summaries. The documentation of each technique was examined to determine how it could be utilized in the environmental analysis of the multiobjective planning framework set out in the P&S. For each method or technique, a technique profile was developed that summarized its salient features. The technique profiles summarize the capabilities of the technique and give the user enough information about its limitations, data requirements, and necessary expertise to make a judgment whether the technique meets the user's needs. This was the purpose of the firsthand examination and summary, as opposed to including only already published abstracts. After actual examination of the documentation of techniques, the following points became apparent:

a. Abstracts of works tend to reflect the requirements or expectations of the sponsor of the research rather than the substance of the work. The language in the abstract may contain terminology such as "comprehensive" and "quantitative" when the correct language should be "comprehensive, but not detailed" and "quantitative for those parameters easily quantified."

_b_. The terminology and jargon used by different agencies and disciplines sometimes mask the fact that agencies are addressing the same problems; only the terminology is different. This can present a problem when abstracts or other summaries are not available. In addition, because of the differences in agency mission, activities that are considered planning functions by the Corps may be considered as operations functions by other agencies. Among Federal agencies, the Corps has developed about the most complex and precise terminology for identifying, describing, and evaluating changes in natural resources.

Scope

6. The results of the methodology and technique review are presented in Appendices A-C. Appendix A, entitled "Tools for Environmental Analysis," consists of discussions of the generic types of environmental analysis methods. This appendix explains the use of methods such as environmental impact matrices for environmental planning.

7. Appendix B contains the technique and methodology profiles prepared from examination and evaluation of technique documentation. Appendix B contains a Methods Section and an EQEP Techniques Section. The Methods Section includes references which may be used to improve the analysis required in the planning steps set out in the P&S. The Techniques Section contains measurement techniques required by the EQEP analysis.

8. Appendix C contains a bibliography of the references, reports, and citations also considered in the review.

APPENDIX A

TOOLS FOR ENVIRONMENTAL ANALYSIS

This appendix describes the generic methods developed for environmental analysis.

Introduction

The National Environmental Policy Act (NEPA), Principle and Standards (P&S), and the Environmental Quality Evaluation Procedures (EQEP) require the use of systematic methodologies, techniques, and procedures for the evaluation of environmental resources affected by water resources projects. Although numerous methods and techniques have been developed to meet the requirements of NEPA, P&S, and EQEP, there is no universal methodology or technique which can be used to meet the environmental evaluation requirements of all water resources projects in all geographical locations. Several methodologies have been described as capable of fulfilling the impact assessment requirements for selected project types in multiple geographical locations. However, these general methodologies are often not sensitive to project design features or local environmental conditions. Accordingly, the most appropriate viewpoint relative to methodologies and techniques is to consider them as tools which can be used in total, or in part, to meet the specific impact assessment needs of a given project type in a given location. Pertinent features of several methodologies can be utilized in a given study to address key environmental issues and impacts. In many cases, individualized approaches must be developed for a given study, with these approaches based on selected principles or information from methodologies and techniques developed for similar or even other types of projects.

Impact methodologies and techniques are not cookbooks for the identification and analysis of environmental effects. No single methodology or technique is appropriate for each planning step or action. Professional judgment must be used both in the selection of an appropriate methodology or technique and its application to a specific water resources project. Interpretation of impact predictions also requires the exercise of professional judgment. Again, impact methodologies and techniques must be viewed as tools to aid the planner in systematically identifying impacts, predicting the associated changes from alternative plans, and appropriately assessing and appraising the significance of the predicted changes.

Purposes of Methodologies and Techniques

Several purposes can be identified for the use of methodologies and techniques in environmental planning. These purposes are not mutually exclusive, nor do each of them have to be satisfied by every methodology or technique applied in every study. The major purposes are as follows:

a. to insure that the appropriate environmental factors are included in the analysis. There are numerous descriptors of the natural and man-made environment which could be used in a planning study. The concept of scoping suggests that these factors should be delimited to allow focus of attention on the most important factors relative to a given project in a specific geographical setting.

b. to assist in the analysis of complex and interrelated environmental features as well as providing the basis for systematic consideration of the effects of a given alternative. The environmental factors affected by water resource projects are often highly interrelated, so that some means is necessary to systematically identify and consider the interrelationships.

c. to aid in the identification of anticipated impacts of an alternative on the environmental resources in a given area.

d. to assist in the quantification of impacts. Quantification of impacts to the extent possible is important because it provides the basic information necessary for the appropriate assessment and appraisal of anticipated changes.

e. to provide a means for evaluation of alternative plans on a common basis. Methodologies can provide a structure for consistent comparison of the features of each plan based on either relative or absolute environmental impact information. Comparison of alternatives on a common basis is necessary if the planning analysis is to play a part in the decisionmaking process.

f. to better communicate impact information and associated summaries. Some methods and techniques give considerable emphasis to the display of impact information. Inclusion of these displays in planning reports assists in the documentation of the planning effort.

Types of Methods and Techniques

There are numerous ways to classify the methods and techniques which have been developed in response to the requirements of P&S and EQEP. For purposes of this presentation, six classifications will be considered -- matrix-based methods, checklists, map/overlay methods, network analysis, comprehensive assessment and evaluation methodologies, and modeling. These types are arranged in order of increasing complexity and, in part, in order of their historical development following the passage of NEPA.

1. Matrix-based Methods

Matrix-based methods originated with the development of the simple interaction matrix for the U. S. Geological Survey in 1971. This simple interaction matrix displayed various project actions along the x-axis, and environmental features along the y-axis. Where a given project action was anticipated to cause an effect on an environmental feature, this was denoted in the matrix by an appropriate code at the action-feature intersection, and followed by a description of the anticipated impact relative to both magnitude and importance. Numerous interaction matrices have been developed for different type projects. Primary strengths of the simple interaction matrix are in impact identification and impact display. The simple interaction matrix does not provide a sufficient approach for actually quantifying anticipated impacts or interpreting or assessing their significance.

Variations of the simple interaction matrix have included stepped matrices or cross-impact matrices wherein the associated changes in environmental features resulting from an initial change in one feature can be delineated. Stepped or cross-impact matrices typically include at least one display of environmental features along both axes, with the usage of this matrix being to identify secondary impacts resulting from initial changes. Again, this type of matrix is primarily useful for impact identification and display.

While matrix-based methods are limited in terms of impact quantification, their usage in the environmental planning process can be beneficial. One usage is related to evaluation of effects by the preparation of matrices on each of the alternatives being evaluated. Matrix-based methods can also be of value in the comparison of alternative plans when the same matrix is applied to each of the plans being evaluated. A useful exercise for the planning team early in the environmental planning process is to prepare a simple interaction matrix to aid in the identification of anticipated impacts. This can be helpful in identifying project features as well as environmental resources which should be delineated in more detail. Another useful exercise can be the preparation of a stepped matrix or a cross-impact matrix for addressing secondary changes resulting from initial changes in environmental resources.

2. Checklists

There are several types of checklists which have been developed for usage with water resources projects. Checklists range from simple listings of environmental features or anticipated impacts of a given project type to comprehensive approaches involving the scaling of the impacts of each alternative on each item in the checklist and the importance weighting of each of the items in the checklist. The latter type of checklist will be described under the heading Comprehensive Assessment and Evaluation Methodologies. Intermediate types of checklists include those that provide considerable descriptive information on the environmental factors and how to predict changes and interpret or assess the changes. Some checklists encourage systematic scaling or ranking of each alternative relative to each item in the checklist.

Simple checklists were developed early following the passage of NEPA since they represented one type of systematic approach for addressing appropriate environmental features related to a project. Simple checklists are useful for identifying environmental resources to be addressed in the inventory step, and they can provide the basis for impact identification for a given project, although this has to be inferred based on considering how each item in the checklist would be changed. Simple checklists can also provide a basis for comparison of alternative plans if the features of each plan and the associated impacts are displayed according to each item in the checklist. This provides a structure for comparison of alternatives and can enable systematic decisions to be made relative to the selection of a recommended plan.

Several descriptive checklists for water resources projects were developed primarily in the middle 1970's, and they continue to be further developed and refined. Descriptive checklists provide detailed information relative to the environmental features in the checklist as well as impact prediction and assessment. These checklists are useful for P&S steps of Inventory, Forecast and Analysis, the Evaluation of Effects, and the Comparison of Alternative Plans. A disadvantage of descriptive checklists is that no emphasis is given to the relative importance of the various environmental features, with this type of judgment left to the user of the checklist. Descriptive checklists can also be used for identifying impacts since the user should examine the impact of each alternative plan on each item in the checklist. Even though an entire descriptive checklist might not be used in conjunction with a given environmental study, familiarity with descriptive checklists and the associated information on impact prediction and assessment can be extremely useful to the planning team.

Scaling or ranking checklists represent that group of methods in which the impacts of each of the alternative plans are displayed on a common impact scale or rank relative to each of the items in the checklist. These methods were initiated some time after development of the simple checklists and continued emphasis is being given to these types of methods. These methods are useful for comparison of alternative plans and can aid the decisionmaking process in selection of a recommended plan. Impact scaling checklists may be based on the use of environmental standards, functional relationships, linear or relative changes, and comparison with the no action alternative. Ranking checklists typically encourage the assignment of a best-to-worst rank to each of the alternatives relative to each of the items in the checklist. These methods are also useful for achieving a systematic evaluation of alternative plans. Disadvantages include potential confusion over the scaling or ranking approach, and the focus of attention on numeric indicators of impact scale or rank to the exclusion of consideration of the actual impacts.

3. Map/Overlay Methods

Another type of method involves the use of a base map with a series of overlays to depict various environmental features. This approach was developed early following the passage of NEPA and, in fact, represents the application of concepts used in more general planning activities. The use of overlay mapping has also been extended to include computer-based mapping for depiction of environmental features in a given area. Overlay mapping can be useful in displaying inventory information for a given geographical location. By appropriate selection of overlays, problem areas can be identified through the use of this type of method. Overlay mapping can also be useful in impact display, although its use in impact identification would be limited. The primary advantage of this type of method is associated with communication of information in a graphic fashion. These methods do not provide information on impact prediction or assessment. Overlay techniques can be useful in communicating information in an environmental impact assessment or impact statement prepared on a given project. Overlay techniques can also be useful in presenting information on alternative plans, thus providing a conceptual framework for the comparison of alternative plans.

4. Network Analysis

Network analysis refers to those methods which display the anticipated impacts of a given project type in a systematic fashion utilizing a series of causative actions and associated environmental changes. Networks were developed in the early part of the decade of the 1970's. Several network analyses have been prepared for water resources projects, including networks for dredging projects, and impoundment and channelization projects. The primary value of a network analysis is for identifying the anticipated impacts associated with a given water resources project. The structure of the network is such that relationships can be shown between changes in one environmental feature and resultant changes in other features. Networks can also be useful for displaying impact information and for organizing the discussion of the anticipated impacts of a given project. In one sense, network analysis techniques represent a variation of the simple interaction matrix, thus they are useful for impact identification as well as impact display.

Even though a network analysis might not be directly utilized in an environmental study, familiarization of the planning team with appropriate network analyses prepared for similar types of projects can provide useful background information prior to detailed planning for specific environmental analysis. The primary planning step where network analysis techniques would be useful is associated with the forecast of environmental changes. Network analysis techniques can also be useful in the evaluation of effects in that the relationships between various environmental changes can be delineated.

5. Comprehensive Assessment and Evaluation Methodologies

Comprehensive assessment and evaluation methodologies refer to a group of methods which are primarily characterized by a composite listing of environmental factors as well as information related to the relative importance of the factors, and information on the scaling or ranking of the impacts of each alternative on the factors in a manner which would lead to a relative evaluation of the alternatives. Weighting-scaling checklists represent the primary type of methodology in this grouping. These methodologies were developed in the mid-1970's, and they continue to be refined and developed as one approach for environmental analysis. This type of methodology is not unique to environmental studies. The basic principles for these methodologies are found in multiple criteria decisionmaking approaches which have been used for a number of years by both governmental agencies and the private sector. This group of methodologies can be useful for identifying potential environmental factors which should be described in the baseline inventory as well as providing information for evaluation of the effects of various alternative plans. These methods can also be useful for comparison of alternative plans and selection of the recommended plan. The primary deficiency in this group of methodologies is that there is oftentimes a lack of information related to actual impact prediction.

The comprehensive assessment and evaluation methodologies tend to be less flexible than other types due to their highly structured nature. Direct application of these methodologies to a given project must be done with care, and in most cases modifications must be made to the methodologies prior to their usage. Resource requirements in terms of baseline data and analytical interpretation are extensive for this category of methodologies. Perhaps the best usage of these methods would be for preliminary evaluation of alternative plans and their internal screening by the planning team. Considerable confusion can arise over the methodologies due to their focus of attention on numeric systems. Another usage of this type of methodology is for purposes of the general grouping of environmental factors as well as the alternative plans. For example, the approaches for importance weighting can be used for grouping the environmental factors into the most important group, least important group, and those of intermediate importance. In like manner, the alternative plans can be grouped or ranked into those representing the better choices relative to a given environmental factor to the worst choice for that particular factor. These methodologies can be useful in conducting trade-off analyses for comparison of alternatives.

6. Modeling

Modeling can be used for environmental analysis with the primary focus on forecasting anticipated changes in environmental factors resulting from a series of alternative plans. Models can range in complexity from simple linear extrapolations to complicated energy systems diagrams. Resource requirements also vary considerably for various modeling approaches. To some extent, modeling has been used since the inception of NEPA, although greater attention has been given in recent years to the development of systems models to describe both the natural and man-made environments. One of the biggest disadvantages of modeling is that the information generated from the models is often misunderstood, and perhaps misinterpreted, particularly by individuals not familiar with the technical details of the model. Modeling probably represents a type of methodology which is of greater potential applicability in the future than it has been in the past.

APPENDIX B

METHODS AND EQEP TECHNIQUE PROFILES

Appendix B contains the technique profiles prepared from examination of documentation of methodologies and techniques. The appendix is divided into a Methods Section and an EQEP Techniques Section. The Methods Section contains profiles of methodologies to support, strengthen, and improve the environmental analysis in the planning steps set out in Principles and Standards. The EQEP Techniques Section contains measurement techniques for the evaluation required by the EQEP.

Contents of Appendix B

METHODS SECTION

The Methods Section contains the technique profiles which support the planning steps set out in Principles and Standards. There are four Profile Characteristic Matrices to assist the user. The matrices are as follows:

(1) General Type Matrix - This matrix shows the basic type of the method, e.g., Comprehensive Assessment Method or Cross-Impact Techniques.

(2) Principles and Standards Matrix - This matrix relates to the methods to the planning steps in Principles and Standards. The matrix shows the planning steps in which the method would be used.

(3) Form of Output/Display - This matrix indicates the type or form of output for each of the methods.

(4) Planning Actions - This matrix indicates the planning action, e.g., data collection, for which the method may be used.

The profiles were developed in as concise a form as possible. For those profiles that were longer or where explanatory material was needed, the explanatory and other material is included in the Extended Profile Section.

TABLE OF PROFILES - METHODS

Table B1

General Type Matrix

Profile Name	Page No. B	Matrix	Comprehensive Assessment Method	Decision/Judgement Analysis Technique	Checklist	Overlay/Map	Interrelationship/Cross Impact Technique	Higher Order Impact Determination	Significance Determination	Classification Technique	Evaluation Methodology	Weighting-Scaling Technique	Remote Sensing	General Reference	Model	Forecasting	Impact Identification and Tracing	Linear Programming Method
Alden	11		X			X												
Bereano	15			X													X	
Canter	18				X													
Carss	20														X			
Carstea	22														X		X	
Central New York	24	X						X										
Christensen	26								X									
Creighton	28															X		
Curran	31				X									X				
Dee	35		X		X						X							
Eckenrode	38			X								X						
Ellis	39									X								
Fischer and Davies	41	X	X									X					X	
Galloway	45			X							X							
Golden	49													X				
Haimes	52																X	
HQDA 1975	56		X		X												X	
HQDA 1979	58												X					
Hendricks	63														X			
Holling	66		X												X			
Jain	68		X		X												X	
Kruzic	71						X											
Lendaris	75														X			
Leopold	79	X																
Linstone	81														X			
Mades	84														X			
McHarg	87					X												
Mitchell	89															X		
Mumpower	92										X	X						
Ortolano	97		X															
Reppert	100				X						X	X						
Ross	103							X							X			
Schlesinger and Daetz	105	X												X				
Sellers and North	108										X						X	
SCS	111													X				
Sorensen	113	X																
States	116														X			
USAE, Tulsa	118											X						
USAE, HEC	121																X	
U. S. Fish and Wildlife	125									X								
Yorke	127																X	

Table B2

Planning Steps From Principles and Standards

Profile Name	Page No. B	Specification of Problems and Opportunities	Inventory and Forecast Water and Land Resource Conditions	Formulation of Alternative Plans	Evalution of Effects	Assessment	Appraisal	Comparison of Alternative Plans	Plan Selection
Alden	11					X			
Bereano	15					X			
Canter	18					X	X		
Carss	20	X				X			
Carstea	22					X			
Central New York	24		X	X	X				
Christensen	26					X	X		
Creighton	28		X						
Curran	31					X			
Dee	35					X	X		
Eckenrode	38						X		
Ellis	39		X						
Fischer and Davies	41	X	X			X		X	X
Galloway	45					X	X	X	
Golden	49					X			
Haimes	52						X	X	
HQDA 1975	56		X			X	X		
HQDA 1979	58		X			X			
Hendricks	63		X						
Holling	66		X			X			
Jain	68		X			X	X		
Kruzic	71	X	X						
Lendaris	75	X	X						
Leopold	79					X			
Linstone	81	X				X			
Mades	84		X						
McHarg	87		X				X	X	
Mitchell	89		X						
Mumpower	92					X	X	X	
Ortolano	97		X			X			
Reppert	100		X						
Ross	103					X			
Schlesinger and Daetz	105		X			X	X		
Sellers and North	108						X		
SCS	111					X			
Sorensen	113					X			
States	116		X			X			
USAE, Tulsa	118						X		
USAE, HEC	121		X			X			
U. S. Fish and Wildlife	125		X						
Yorke	127					X			

Table B3

Form of Output/Display

Profile Name	Page No. B	Quantitative	Matrix	Network Diagram	Map/Overlay	Hierarchy/Graph	Classification	Computerized	Other	Model
Alden	11				X				X	
Bereano	15			X						
Canter	18								X	
Carss	20					X				
Carstea	22	X								
Central New York	24		X							
Christensen	26								X	
Creighton	28	X								
Curran	31	X								
Dee	35	X								
Eckenrode	38	X								
Ellis	39						X			
Fischer and Davies	41		X							
Galloway	45	X						X	X	
Golden	49								X	
Haimes	52	X								
HQDA 1975	56	X	X							
HQDA 1979	58				X		X			
Hendricks	63	X								
Holling	66	X								X
Jain	68	X								
Kruzic	71	X								X
Lendaris	75									X
Leopold	79		X							
Linstone	81									X
Mades	84									X
McHarg	87				X					
Mitchell	89	X								
Mumpower	92	X				X		X		
Ortolano	97	X								
Reppert	100	X								
Ross	103					X				X
Schlesinger and Daetz	105		X							
Sellers and North	108	X								
SCS	111		X	X					X	
Sorensen	113			X						
States	116									X
USAE, Tulsa	118	X	X							
USAE, HEC	121	X								
U. S. Fish and Wildlife	125						X			
Yorke	127		X						X	

Table B-4

Planning Actions Matrix

Profile Name	Page No. B-	Data Collection	Data Analysis	Inventorying	Forecasting	Impact Assessment	Evaluation	Other
Alden	11			X		X		
Bereano	15					X	X	
Canter	18					X	X	
Carss	20		X					
Carstea	22					X		
Central New York	24			X		X		
Christensen	26						X	
Creighton	28				X			
Curran	31				X	X		
Dee	35				X	X	X	
Eckenrode	38						X	
Ellis	39	X	X	X				
Fischer and Davies	41			X		X	X	
Galloway	45						X	
Golden	49	X	X			X	X	X
Haimes	52						X	
HQDA 1975	56			X		X		
HQDA 1979	58	X	X	X				
Hendricks	63				X			
Holling	66				X	X		
Jain	68	X	X	X	X	X	X	
Kruzic	71				X			
Lendaris	75		X					
Leopold	79					X	X	
Linstone	81					X	X	
Mades	84						X	
McHarg	87			X		X	X	
Mitchell	89				X			
Mumpower	92						X	
Ortolano	97	X	X		X	X	X	
Reppert	100			X				
Ross	103					X		
Schlesinger and Daetz	105					X		
Sellers and North	108						X	
SCS	111					X		
Sorensen	113					X		
States	116	X	X	X				
USAE, Tulsa	118						X	
USAE, HEC	121						X	
U. S. Fish and Wildlife	125			X				
Yorke	127					X		

1. Name:

Alden, Howard R., "Environmental Impact Assessment: A Procedure for Coordinating and Organizing Environmental Planning," Technical Publication No. 10, Thorne Ecological Inst., Boulder, Colo.

2. Description:

This technique was developed for use in assessment and evaluation of development impacts on forests and/or similar types of land use changes. It is a method to systematically analyze the relationships and interactions of environmental resources. This technique assists in analyzing the strength of interactions and identifying those resources which exert the strongest effects on other resources. The assessment of impacts on environmental resources is carried out at a gross level, e.g., the resources considered are hydrology, vegetation, soils, and limnology. The resources in a project area are mapped, similar to procedures described in the McHarg profile.

Interrelationships among resources are determined through use of a Strength-of-Relationship (SOR) matrix as shown in Table 1. Resources are considered to be active forces affecting the quality and/or quantity of other resources. The strengths of the interrelationships are rated as None, Low, Moderate, or High. Examination and interpretation of the SOR ratings indicate the strength of relationships, relative importance of a resource as an active force affecting other resources, and the sensitivity of resources to the active forces of other resources.

In examining the SOR matrix, it is possible to deduce which few resources have the strongest relationships or the greatest number of relationships with other resources. These resources will be the most sensitive to modification by project actions; it may be said that these are the driving or critical resources.

Impact assessment is accomplished through an Environmental Response Unit (ERU) analysis. The concept of ERU seeks to explain the resource dynamics of an impacted area in order to systematically and comprehensively consider the impacts of a proposed action.

The bases for the ERU analysis are the resources determined to be the driving or critical resources in the SOR matrix analysis. Potential impacts are considered for the resources singly and for the resources as they interact. Graphically, this is represented in Alden Figure 1, Extended Profile Section.

Components A, B, and C are the spatial distribution of the driving or critical components of a study area. Areas D, E, F, and G of Figure 1 represent the integration or interaction of the environmental components.

Project Environmental Component	1	2	3	4	5	6	7
1 Vegetation	High	Mod	Low	None	High	None	High
2 Mammals	High	None	Low	Low	Mod	Low	High
3 Birds	High	Low	None	Low	Mod	Low	High
4 Fisheries	Mod	Low	Low	Mod	High	High	Mod
5 Hydrology	High	None	None	None	None	Mod	High
6 Limnology	Mod	None	None	Low	High	Mod	Mod
7 Soils	High	Low	None	None	High	None	None
	Vegetation	Mammals	Birds	Fisheries	Hydrology	Limnology	Soils
	Active Forces (Horizontal Axis)						

Table 1. Composite Strength of Relationship Matrix

The delineation of the relationship of an environmental component to other components is done to determine the processes or resources the components affect. Analysis of the relationship of the Soils, Hydrology, and Vegetation ERU is provided in Alden Table 2. It is noticed that such things as Wildlife Habitat, Evapotranspiration, and Runoff appear repeatedly in the table indicating their sensitivity to changes in a number of ERUs.

To determine the extent of impact of a proposed project, the ERUs are mapped and then the project features are overlaid on the ERUs. According to the author, "Significant to the mapping is that experts in the various resource disciplines are required to display both quantity and quality attributes of the resources on the maps. These interpretive type maps are supported by study reports and are intended to provide a definitive evaluation of the quantity and quality of resources modified on a location by location basis."

The remainder of the analysis relies on ratings of the impacts identified through analysis of the map graphics and ranking alternatives by their impacts on environmentally sensitive resources.

3. Applicability:

The SOR matrix and ERU delineation provide a method to systematically delineate and characterize components of the environmental system of a project area. Delineating the relationships of the resources assists in tracing impacts.

Use of mapping techniques for impact assessment is helpful in determining changes in land use as impacts can readily be measured in acres.

The SOR matrix and ERU delineation could be used to Inventory and Forecast conditions in the planning area. In the Evaluation of Effects step, this procedure may be used for assessment of effects of alternative plans.

The SOR matrix and ERU delineation process may be used to identify the relationships and interactions of resources in the Environmental Quality Evaluation Procedures. This process would be of assistance when developing the evaluation framework for the Ecological Attribute to identify resource interactions.

The qualitative level of analysis presented in this methodology would be appropriate for early stages of planning.

4. Advantages and Disadvantages:

An advantage of this method is that it provides a way to systematically identify interrelationships between resources and to graphically display the interrelationships in terms of the mapped ERUs. The identification of interrelationships can then assist in the tracing of impacts resulting from changes in each of the resources.

5. Previous Uses:

6. Source/Contact:

   Dr. Howard R. Alden, Department of Recreation Resources, Colorado State University, Rm. 233, Forestry, Fort Collins, Colo. 80523

1. Name:

Bereano, Philip L. et al. 1973. "A Proposed Methodology for Assessing Alternative Technologies," Technology Assessment, Vol I, No. 3, pp 179-190.

2. Description:

This article describes a methodology for evaluating alternatives. The methodology integrates a number of tools for environmental analysis. Bereano et al. builds on the concepts of network analysis of Sorenson and matrices work of Leopold.

The authors state that their main innovation is the concept of the effects chain which helps one determine which and how many parameters are required to capture the vital information about impacts of an activity. An effects chain is a graphic display of all the effects flowing from a single starting point. Of course, the effects chains and their starting points relate to the various alternatives, but they should be as independent as possible of the alternatives. Any effect that is relevant to at least one alternative should be included in the analysis, as each effect should be useful in comparing all the alternatives with one another. To be exhaustive, all possible higher order effects should be expressed at every branch created in the chain. For analysis of the Alaskan pipeline, three effects chains were developed for

a. Construction of pipeline and associated systems.

b. Normal operation of pipeline system.

c. Accident causing disruption to the pipeline system.

Early in the development of effects chains the authors realized the need for endpoint criteria. Most effects chains did not develop with obvious endpoints; rather, a rational justification was needed for ending each chain. Each chain ends at higher order effects relevant to the evaluation of the alternatives' parameters. The criteria for determining these parameters are: (1) sufficient data to proceed are lacking; (2) the endpoint is given in the assignment or proposal; (3) any further disaggregation of effects would be superfluous by no longer serving to differentiate among parameters; and (4) any further disaggregation of an effect would be superfluous because the disaggregated terms result in an analysis identical to that of the aggregated term (Figure 1).

After development of the effects chain, the endpoints are used as the input to a decision matrix. Impacts on the endpoint parameters are used to evaluate the alternatives. The decision methodology set out has the user make judgments about

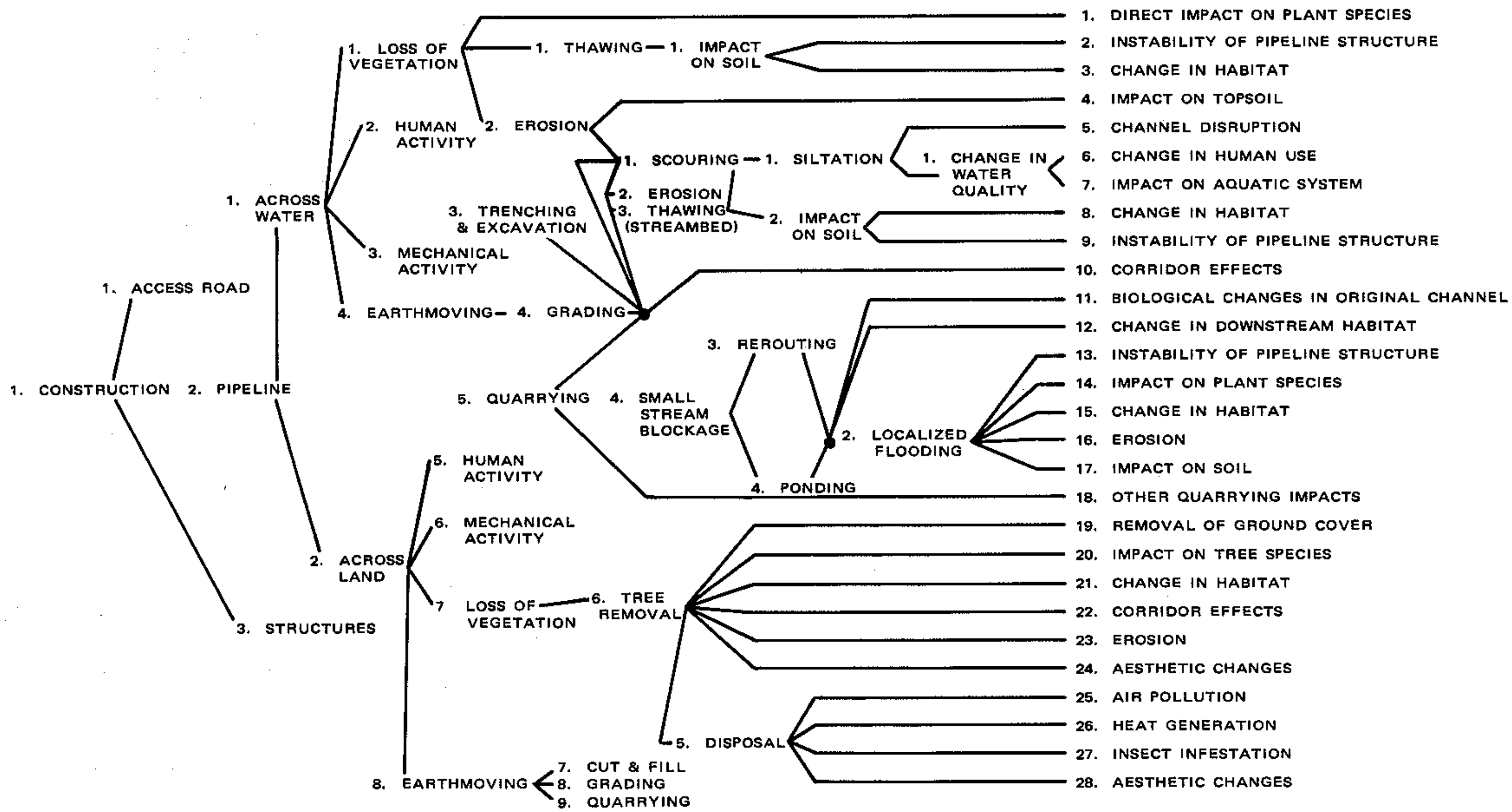


Figure 1. Construction Effects Chain

a. The importance of each parameter.

b. The probability of occurence of the impacts.

c. The significance of the impacts, called utility (i.e., a scaling of the impacts).

Weighted values for each impact are calculated as the product of the utility and probability. Alternatives are then composed on the basis of the weighted values of their impacts.

3. Applicability:

The concepts on the development and use of the effects chain provide a mechanism to identify and trace impacts. Development of the effects chains requires the planner to systematically delineate impact pathways. This can assist in clarifying complex relationships and interactions. By providing criteria for endpoints in the effects chains, and then using the endpoints as parameters in the decision matrix, a reasonable number of relevant parameters are chosen for use in the matrix.

4. Advantages and Disadvantages:

An advantage of using the effects chain concept is that it assists in identifying the critical impacts which may occur and limiting the input to the decision matrix to these critical impacts. A disadvantage in using such an approach is that the decisions on which impacts to include may in some cases be based on subjective judgment, which may be open to disagreement dispute.

5. Previous Uses:

The methodology has been applied to the Alaska Pipeline controversy using as data the Final Environmental Impact Statement--Proposed Trans-Alaska Pipeline. That application is described in Bereano.

6. Source/Contact:

Dr. Philip Bereano, Program in Social Management of Technology, 316 Guggenheim, FS-15, University of Washington, Seattle, Washington 98195

1. Name:

Canter, Larry W. 1979. "Environmental Impact Statements on Municipal Wastewater Programs," Information Resources Press, Washington, D. C.

2. Description:

Of the environmental impact methodologies developed, the checklist methodology has been extensively used for a wide range of project types. Utilizing a checklist for impact assessment and evaluations assists in a systematic approach to the tasks of impact assessment and evaluation.

This report is the result of a study of 28 environmental impact statements (EISs) prepared for wastewater facility 201 plans under EPA's Construction Grants Program. The substantive review and analysis was undertaken to identify strengths and weaknesses in the EISs and to develop recommendations for improving EISs on wastewater facility plans. The EISs were reviewed on a number of issues including: identification of specific water quality problems or needs; adequate description of the environmental setting; consideration of alternatives; identification of mitigation measures; and issues considered in the sections such as short-term changes versus long-term productivity and on irreversible and irretrievable commitments of resources.

The EISs were examined to determine if an impact assessment methodology was used in evaluation and selection of an alternative. Twenty of the impact statements used a methodology to assist in selection of an alternative. These 20 all utilized some form of checklist methodology to account for impacts of alternatives. Five types of checklists were utilized in the 20 EISs. Descriptive checklists consider a series of factors, and qualitative information is presented on the impacts of alternatives on these factors. Ranking checklists rank the potential impacts of alternative from best to worst in terms of the identified factors. Scaling checklists involve assignment of an algebraic or letter scale value to the impact of each alternative of each identified factor. The weighting/ranking checklist recognizes that the factors involved in comparing alternatives are not of equal importance; relative weights are thus assigned to identified factors. These weights are then considered in combination with the rankings of each alternative. The weighting/scaling checklist uses the same concepts as the weighting/ranking checklist with composite scores developed for each of the alternatives on the basis of its weight and scale. Of the 20 EISs utilizing a checklist methodology, there were 4 descriptive checklists, 4 ranking checklists, 6 scaling checklists, 1 weighting/ranking checklist, and 5 weighting/scaling checklists. Examples of the analysis produced from ranking, scaling, and weighting/scaling checklists are included in the Extended Profile Section, Figures 1-3.

3. Applicability:

This report deals with the impacts, alternative strategies, and mitigation associated with wastewater treatment plants. The chief value of this report to Civil Works function is the comparison of the evaluation produced by utilizing different types of checklists for use in the Evaluation of Effects.

4. Advantages and Disadvantages:

The advantages in use of a checklist methodology are in the systematic, flexible approach to impact assessment. The impacts of all alternatives are displayed so that the trade-offs between alternatives are clearly presented.

Disadvantages of using a checklist methodology such as a ranking or weighting-scaling checklist are that judgments used in assigning rankings, weights, and in scaling may be disputed.

5. Previous Uses:

This report includes a number of the checklists used in the EISs examined in the study. (See Extended Profile Section.)

6. Source/Contact:

Dr. Larry Canter

1. Name:

Carss, Brian W. 1979. "Conducting Interpretive Structural Modeling (ISM) Without a Computer," Unpublished (Complete profile contained in Extended Profile Section)

2. Description:

Interpretive Structural Modeling (ISM) is a technique for organizing, clarifying, and articulating relationships between the various elements of a complex system or problem. (For an extensive explanation of ISM, see Lendaris Profile, computer-guided ISM.) ISM is utilized where there is unclear, incomplete, or vague understanding about the relationships between various elements or concerns being considered. ISM might be used to define the relationship between environmental resources, or between planning objectives, between public concerns, between environmental resource problems or opportunities, or between impacts of alternatives. The ISM process is based on respondent's answers to questions about the relationship between the elements (e.g., "Does fulfillment of planning objective X contribute to fulfillment of planning objective Y?" or "Can impacts on dissolved oxygen and turbidity be subsumed under impacts on water quality or are they important enough to be considered separately?") The output of ISM is in the form of a hierarchy or graph which exhibits the relationship of elements within the system. After the initial hierarchy is formed, it may be amended as more definitive data are available to clarify or improve projections, relationships, or impacts. For problems or systems with less than 30 elements, the manual system may be used. The use of ISM without a computer is outlined in the Extended Profiles.

3. Applicability:

ISM is most useful when attempting to establish and/or clarify the relationships among elements in complex, interacting systems. ISM could be used to structure and define the relationship of:

a. Problems and opportunities.

b. Environmental resources.

c. Planning objectives.

d. Environmental impacts.

e. Public concerns.

ISM is thus most useful for the Specification of Problems and Opportunities and Evaluation of Effects Steps. ISM can be used as a technique for group learning and communication that can be utilized within the planning team, as part of public participation, or for identification of conflict and consensus. ISM can be used as a management tool to focus discussion by clarifying the relationships among complex or interacting systems.

4. Advantages and Disadvantages:

Although this technique frees users from depending upon computer hardware, it has the disadvantages that large numbers of elements, e.g. problems or opportunities, are difficult to handle manually and the system does not help one draw a two-dimensional diagram or a hierarchy of the problem as will the computer-assisted ISM.

5. Previous Uses:

The general technique has been applied in the United States by John N. Warfield, University of Virginia; David Malone, Catholic University; and others. Also see the Lendaris profile.

6. Source/Contact:

Dr. Brian W. Carss, Department of Education, University of Queensland, St. Lucia, Queensland, Australia

1. Name:

Carstea, D. et al. 1975. "Guidelines for the Environmental Impact Assessment of Small Structures and Related Activities in Coastal Bodies of Water," MTR-6916, Rev 1, The MITRE Corporation, McLean, Va. (Prepared for U.S. Army Engineer District, New York, CE, New York, N.Y.).

2. Description:

This report was prepared to provide the necessary information for quantitatively assessing the impact of certain projects requiring Section 404 permits. Types of projects addressed by this report include riprap placements; bulkheads; piers, mooring piles, dolphins and ramps; dredging; outfalls; submerged lines and pipes; and aerial crossings. Although these specific types of projects are not usually within the purview of CE multiobjective planning, they may form part of alternative plans; for example, riprap placement or construction of piers and ramps may be part of an alternative considered in a reservoir study.

For each project type, there is an explanation of the purpose, use, and typical construction procedures for the structure. The construction and operation of the structure is considered in terms of quantitative impacts on water quality; erosion, sedimentation, and deposition; flood heights and drift; effects on biota and wetlands; air quality; noise; safety/navigation; recreation; aesthetics; and socioeconomics. Such things as air emission loads and expected changes in water volume are included to assist in projecting impacts. For each project type, a case study which illustrates the typical impacts is provided.

Appended to the report are models which can be used to project stormwater runoff, water quality changes, air quality changes, and soil erosion. The stormwater runoff model utilizes soil types, antecedent moisture and rainfall intensity to predict runoff. The projected runoff is then used to calculate pollutant loads using observed stormwater pollutant concentrations. The water quality model is a dilution technique which predicts the dispersion of a pollutant. This model is designed for use in a tidal or estuarine environment. The air quality model utilizes a dispersion method to estimate the effects of emissions on ambient air quality. The erosion model is the Universal Soil Loss Equation.

3. Applicability:

The discussion of impacts of construction and operation of the types of structures could be used when the various structures are part of alternatives under consideration. The models presented would be applicable to the Evaluation of Effects Step to identify and trace impacts and to measure impacts.

4. Advantages and Disadvantages:

This report provides a quantitative approach to assessment of the impacts of different types of structures requiring a Section 404 permit. Utilization of the report information and models is limited, due to the fact it was prepared specifically for use in the northeast United States; the methodology may require modification to apply elsewhere.

5. Previous Uses:

Case studies documenting the assessment of impacts for each type of structure are presented.

6. Source/Contact:

1. Name:

Central New York Regional Planning and Development Board. 1972. "Environmental Resources Management," Report No. CNYRPDB-RP-72-HUD-246-06, Syracuse, N. Y. (Prepared for Department of Housing and Urban Development, Region 2, New York, N. Y.)

2. Description:

This report contains two environmental planning techniques developed for regional land use planning. The two techniques are an environmental impact matrix methodology and a land use evaluation technique. Examples of the matrices and a display of the land use evaluation are included as Figures 1-3 (CNYRPDB) in the Extended Profiles Section.

The matrix technique utilizes a stepped matrix approach. The initial matrix pairs various development actions (e.g., tree removal, land filling, or stream channelization) and resource conditions (e.g., steep slopes, wetlands, or high water table). The second matrix combines primary impacts and secondary impacts. To utilize this matrix approach, first the primary impacts of the development procedures on the resource conditions are assessed. In cells of the matrix (Figure 1), the primary impacts expected for each resource are noted with numbers. The numbers represent primary impacts (e.g., erosion of slope, bed, or streambed increased; surface runoff increased; and fish habitat increased).

The second matrix (Figure 2) is used to show the relationship between the primary impacts and any induced secondary impacts. The cells within the matrix are coded to show whether the primary impact is a major or a minor and a direct or an indirect cause of the secondary impact. For instance, for the primary impact of increase in surface runoff, secondary impacts include: sedimentation increased; volume and rate of streamflow increased; and aquatic plant growth decreased. The increase in sedimentation is judged a major indirect impact and the increase in streamflow is a major direct impact.

The use of these specific matrices is dependent on an understanding of the characteristics of resources and how the resources respond to development activities in addition to understanding the relationship between resources and secondary changes which may be induced.

The land use evaluation methodology is a ranking system to evaluate compatibility of land with specific uses. The technique delineates 13 land capability classes. The 13 classes include designations such as wildlife habitat, floodplain management areas, prime agricultural lands, and outdoor recreation areas. Each class is evaluated by ranking the class' suitability for a potential use. A completed capability table would appear as in Figure 3.

3. Applicability:

The stepped matrices could be utilized for the impact assessment. After the matrices are constructed for a specific project, the matrices could then be utilized for future projects of the same type.

The land use ranking techniques would be appropriate for Formulation of Alternative Plans or in the Inventory of Water and Land Use Conditions.

Because of the qualitative nature of analysis produced with both of these techniques, they would be appropriate for use early in the planning process.

4. Advantages and Disadvantages:

The impact assessment matrices clearly delineate the impact of development activities, tracing these to secondary and higher order impacts. This technique is similar to that described by Sorenson with specific application to land use changes.

In application of the matrices disagreement may arise over the relationships of the primary impacts to secondary impacts and the judgments of major or minor and direct or indirect secondary impacts. The standards, policies, and rankings used in the land use capability evaluation technique are likewise open to such disagreement.

5. Previous Uses:

6. Source/Contact:

1. Name:

Christensen, Sigurd W., Van Winkle, Webster, and Mattice, Jack S. 1975. "Defining and Determining the Significance of Impacts; Concepts and Methods," in Proceedings of the Conference on the Biological Significance of Environmental Impacts, U. S. Nuclear Regulatory Commission, Report NR-CONF-2, pp 191-219.

2. Description:

After environmental impacts of alternatives have been assessed, both the Principles and Standards (P&S) and the Environmental Quality Evaluation Procedures (EQEP) require that the impacts be appraised, e.g., judgments made as to the beneficial or adverse nature of the impacts. These judgments are made on the basis of professional judgment and guidelines are developed in the EQEP process. The conceptual framework presented in this paper (Figure 1) provides one conceptual and procedural framework for the appraisal process.

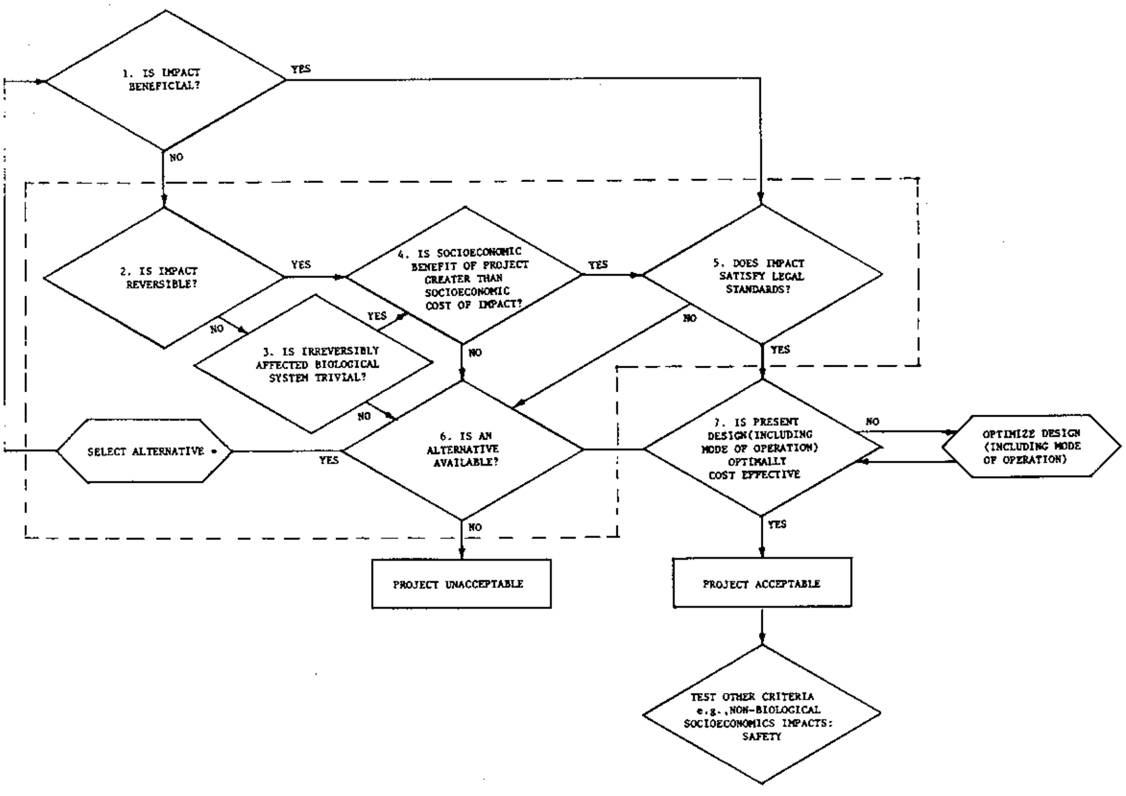


Figure 1. Framework for Appraisal of Impacts and Determining Acceptability of an Alternative

The process presented was developed to appraise the biological impacts and use the impact appraisals to determine acceptability of a project.

The concepts and definitions used by Christensen are consistent with P&S and the CE planning guidance. Using the framework presented by Christensen, the criteria (questions) could be expanded to meet CE needs. For instance, Box 5 could be expanded to "Does the impact violate an institutional, public, or technical concern, criteria, or limit?" This would identify significant impacts as required by EQEP. Similarly Box 2 could be expanded to consider the duration, location, magnitude, or other impact characteristics.

3. Applicability:

The appraisal framework developed by Christensen is conceptually sound and consistent with P&S and EQEP. The framework could be expanded to use in determining significance of impacts and appraising the impacts under EQEP and P&S. The use of the framework to determine the acceptability of an alternative goes beyond the scope of EQEP.

4. Advantages and Disadvantages:

The conceptual framework formalizes the determination of impact significance. As a flexible framework, it may be modified to accommodate policy and regulation requirements or whatever considerations are considered germane to the study at hand.

5. Previous Uses:

The authors' concept and definitions are applied to impact projections for the striped bass made by Oak Ridge National Laboratory. The predictions are accomplished by means of two computer simulations: a young-of-the-year population transport model and a life-cycle population model. Such models help one estimate relationships between power plant designs and the striped bass population size during a period of 100 years. The projections also shed some light on the cumulative effect of the proposed power plant in the context of impacts resulting from plants already in operation on the Hudson River.

6. Source/Contact:

Sigurd W. Christensen, Environmental Sciences Division, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn. 37830

1. Name:

Creighton, James L. 1976. "Alternative Futures Planning," Engineering and Research Center, Bureau of Reclamation, Denver, Colo.

2. Description:

This report presents the procedures for using alternative futures in planning. The alternative futures approach recognizes that there exist a number of possible future conditions, rather than a single most probable future. The existence and specification of these future conditions are predicated on the assumptions made about future conditions. If one set of assumptions is used, for example, that demand for water will continually increase in the next 50 years, a certain set of alternatives will be developed. If the assumptions are instead that water demand will increase to a point and then level off, a vastly different set of alternatives may be developed. Because the assumptions which are used to develop alternatives dictate the alternatives developed, it is important that the range of possible futures be considered. In addition, there may be conflicting or differing views about the desirability of such things as growth versus nongrowth and other social and political questions. The consideration of a range of alternative futures is important because it can increase the range of alternatives developed.

The process set out to use alternative futures in planning involves identifying current and potential future trends and developing plans to address each future condition. Sequentially, the process is as follows:

a. Identify Factors Which Affect the Future - This step may be addressed in identifying the problems and opportunities existing in a study area. This involves identifying the political, economic, or environmental factors that will affect the future of the study area. These factors may include such diverse things as energy availability, changes in water quality standards, local controls on growth, and availability of public transportation. The widest range of factors possible is to be considered.

b. Identify Themes - In examining the identified factors, some of the factors may be so important that a major change in that factor could in itself create a fundamentally different future. These factors affect the other factors. The other factors are dependent in the sense that if this one factor changes, then all other factors are affected accordingly. These major factors are called themes because they can serve as a core around which to organize projections of future conditions. Themes may include the following:

(1) Severe energy shortage.

(2) Urban growth.

(3) Suburban growth.

(4) No growth.

c. Develop Alternative Future Scenarios Based on the Themes - Each of the themes is used as the basis to develop a scenario in response to the theme. A way to approach this is to evaluate each dependent variable in light of that theme. Such an analysis is represented as follows, from Creighton:

Theme	Dependent variables	Elements in scenario
Major Energy Shortages	(a) Development of alternative energy sources	(a) Emphasis on power from nuclear and solar sources
	(b) Environmental regulations	(b) Strong pressure to reduce environmental standards regarding construction of power plants
	(c) Agricultural cropping patterns	(c) Change in cropping patterns toward "energy-efficient" crops

The evaluations of dependent variables are combined to describe the most probable scenario of the future assuming the particular theme. These scenarios not only describe the future conditions, but provide the basis to make projections on such things as future population, development patterns, and use of water and other natural resources.

d. Identify Natural Resource Requirements for Each Scenario - After development of each scenario, it will be possible to project the natural resource needs associated with each scenario. The scenarios provide some guidance as to the requirements. For example, a scenario based on a strong environmental theme may preclude water supplies that would require major construction projects, whereas in another scenario, the same supply may be a desirable alternative.

e. Identify the Most Desirable Plan for Each Scenario - Each scenario is considered, and an alternative plan is developed which best addresses the scenario. These alternative plans respond to the question, "If this scenario is the best estimate of the future, what would be the best plan to meet the natural resource requirements described in the scenario?"

f. Identify Decisionmaking Sequence for Each Plan - This step determines what decisions would have to be made and in what sequence if each alternative were to be implemented. Where possible, time estimates should be made on when decisions would have to be made.

g. Cross-Impacting Analysis - Cross-impacting entails considering each plan and its component decisions and determining, if one plan is implemented, if the other alternatives could still be carried out. Each decision is evaluated as to the degree to which it decreases flexibility to implement another alternative.

h. Developing a Recommended Plan - The recommended plan, or operating plan, is developed with the goal of preserving as many of the desirable options as possible and making decisions which decrease flexibility no sooner than they need to be made.

i. Identify Assumptions for Major Decision Points - This involves documenting the assumptions used in making decisions. The operating or recommended plan contains major decision points. Documenting the assumptions necessary for each decision point increases the tractability and credibility of the planning effort.

3. Applicability:

Alternative futures provide a method for developing a range of alternatives based on various assumptions about the future. The scenarios developed during the effort provide a framework for forecasting future conditions and developing alternatives responsive to the forecasts. The primary thrust in the alternative futures method is to identify plausible future conditions, and thus consideration of alternative futures is appropriate where there is a lack of consensus on the most probable future.

4. Advantages and Disadvantages:

Advantages in using alternative futures are that its use can increase the number of alternative plans or options which are considered. Use of alternative futures ensures that a range of alternatives be considered. A disadvantage of using alternative futures is that it increases the number of forecasts required because more than a single probable future must be considered.

5. Previous Uses:

Alternative futures were used in developing alternatives in Metropolitan Region, Omaha, Nebraska - Council Bluffs Iowa Study, Omaha District.

6. Source/Contact:

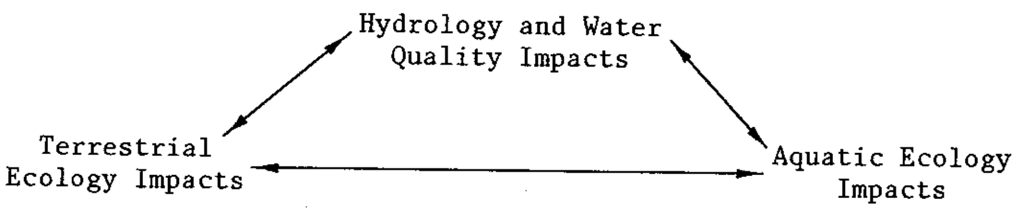
James L. Creighton, SYNERGY Consultation Services, Saratoga, Calif.

1. Name:

Curran Associates, Inc. 1976. "Guidelines for Review of Environmental Impact Statements--Vol IV, Channelization Projects," Northampton, Mass. (Submitted to Environmental Protection Agency, Washington, D.C.)

2. Description:

This report was developed to serve as a guide to the review of EISs on channelization projects. As such, it can serve as a descriptive checklist methodology for assessing and evaluating impacts of proposed channelization projects. The report summarizes research on the effects of channelization and discusses impacts utilizing the following framework:



The three types of impacts are considered separately and interrelationships and cross impacts are identified.

The report identifies the impacts of channelization on hydrologic and water quality parameters. The cause-effect relationships of impacts of construction and maintenance activities are identified. Data sources are identified as well as extensive referencing to available research on specific impacts. In addition, appropriate forecasting models are presented. Channelization projects are undertaken to improve hydrologic efficiency. To accomplish this may require clearing and snagging, streamside excavation, deepening of the channel, or combinations of these and other measures. These activities have a wide range of water quality effects on the channelized reach as well as on downstream reaches. Alterations to the stream which increase water velocity increase turbidity and sedimentation downstream. Excavation which destroys riparian vegetation reduces shading of the channel, thus increasing water temperature. Increasing the hydrologic efficiency reduces overbank flooding which may diminish groundwater recharge. A discussion of measures to mitigate impacts is included. The identification and assessment of impacts on hydrologic and water quality parameters are summarized in Table 1, Extended Profiles Section.

The impacts to the aquatic ecosystem are discussed under the broad categories of physical habitat alteration and changes in land use and water quality. "Most of the ecological impacts of channelization can be related to the introduction of uniformity into a naturally diverse system whether by straightening, removal of obstructions, or bank vegetation or any other actions." The impacts on aquatic ecology are summarized in Table 2, Extended Profiles Section.

Aquatic habitats are altered through removal of debris and riparian vegetation and through channel excavation and maintenance. Clearing of instream debris constitutes habitat destruction for some aquatic communities. Debris-laden areas often serve as shelter, feeding, and reproduction areas for fish, insects, and other organisms. The clearing of bankside vegetation increases the likelihood of streambank erosion. Removal of vegetation alters the sunlight-shade pattern that is conducive to organisms with differing preferences for light intensity, thereby contributing to habitat diversity. Channel excavation produces long-term changes in the nature of the streambed and bank. These changes produce changes in the stream gradient and flow regime. Increasing the stream gradient and flow alters turbidity and sedimentation patterns. Replacing a gravel substrate with an unstable sandy bottom will eliminate many species of benthic invertebrates causing a decrease in species diversity. Filter feeding invertebrates may be eliminated or reduced in number due to interference with feeding by suspended solids. Fish populations are altered by sedimentation and turbidity by interfering with feeding, reproduction, and respiration. Suspended solids can abrade gill filaments, thereby impairing respiration. Feeding patterns may be altered due to reduced olfactory and visual sensitivity. In addition, sediments may cover benthic food supplies. Sedimentation can cover spawning areas thus impacting on reproduction.

Changes in land use as the result of a channelization project generally involve drainage of agricultural lands or wetlands. Drained wetlands may be filled to increase agricultural acreage. These changes in land use would be expected to induce changes in water quality due to increased nutrient and pesticide levels. The growth of algae and rooted aquatic vegetation may be stimulated by an increase in nutrient levels. A concluding section provides technical criteria and/or guidelines for evaluating impacts to aquatic ecology.

Impacts to terrestrial ecology, like those to aquatic ecology, are categorized as either changes in habitat or as changes in land use. Terrestrial impacts are most easily and obviously associated with the construction activities responsible for alteration of existing soils, vegetation, and habitats alongside channelized sections. These impacts are summarized in Table 3, Expanded Profile Section.

Changes in water quality and hydraulic parameters occurring as a result of channelization may bring about changes in species composition of streambank vegetation. A change in groundwater levels may have a strong influence upon vegetational changes along channelized streams. Plant-soil moisture relationships are thereby changed and plants more tolerant of xeric conditions may invade the area, or growth rates of existing species may be affected. Changes in stream velocities may cause changes in bank stability and therefore in the kind and/or maturity of plants and animals preferring such riparian niches.

Riparian habitats provide not only food, but also shelter and protective cover. Disturbance or removal of this habitat by excavation, burying with dredged materials, clearing, or bank-stabilization measures introduces new factors in the area's population dynamics--as, for example, in changing predator-prey relationships or limiting food supply.

The effects of channelization projects on wetland habitats are due primarily to reducing inundation and draining of wetlands. Wetland drainage can be expected to lower groundwater levels as drained areas dry out. A shift in vegetational species will then gradually occur, followed by a change in resident wildlife species better adapted to the invading dryland vegetational types. In many cases, drainage projects have decreased the diversity of both vegetational and animal species over extensive areas. Channels which pass through or alongside wetlands areas may have the unintended effect, because of adjunct features (e.g. berms or spoil banks), of restricting or preventing periodic inundation and replenishment of adjacent wetlands.

Coincident with drainage and/or flood reduction measures which have an impact upon wetlands may be the construction of access roads, some of which may be along spoil banks. Construction and subsequent use of these roads, in an area previously undisturbed by recreational and exploitative activities, may be a serious source of environmental impacts.

Migratory birds, especially waterfowl, are notable users of wetlands on a seasonal basis. Such areas may serve either as transient resting places or as places of longer residence, depending upon their location along regional flyways.

The emplacement of spoil and dredged materials in wetlands adjacent to a channel will have the effect of destroying one kind of habitat and replacing it with another. The addition of nutrients derived from dredged materials may add appreciably to the nutrient loading of the wetland in which they are dumped.

A section is included which provides technical criteria and/or guidelines for evaluating impacts.

3. Applicability:

The checklist methodology contained in this report could serve as a guide to the preparation of a channelization EIS. The checklist could guide the Evaluation of Effects step to identify and trace impacts, and to measure impacts. The section dealing with the Evaluation of Impacts provides technical criteria which could be used in the appraisal of impacts.

4. Advantages and Disadvantages:

Use of this descriptive checklist provides a systematic approach to the impact assessment task. The sections on hydrology and water quality impacts present quantitative models and predictive techniques. Predictive techniques for the other impacts, however, are not presented.

5. Previous Uses:

6. Source/Contact:

1. Name:

Dee, Norbert et al. 1972. "Environmental Evaluation System for Water Resources Planning," Final Report, Battelle-Columbus Laboratories, Columbus, Ohio (Prepared for Bureau of Reclamation, Department of the Interior, Washington, D. C.)

2. Description:

The Environmental Evaluation System (EES) was among the first weighting-scaling methodologies developed for evaluation of environmental impacts. As such it is well known and cited frequently in the literature. It is for this reason that this EES profile is included.

The EES is a quantitative evaluation technique based on weighting of environmental parameters and scaling of impacts (impacts are scaled on 0.0-1.0 scale) of a proposed project. The environmental parameters to be assessed are arranged in a hierarchical evaluation framework (Figure 1).

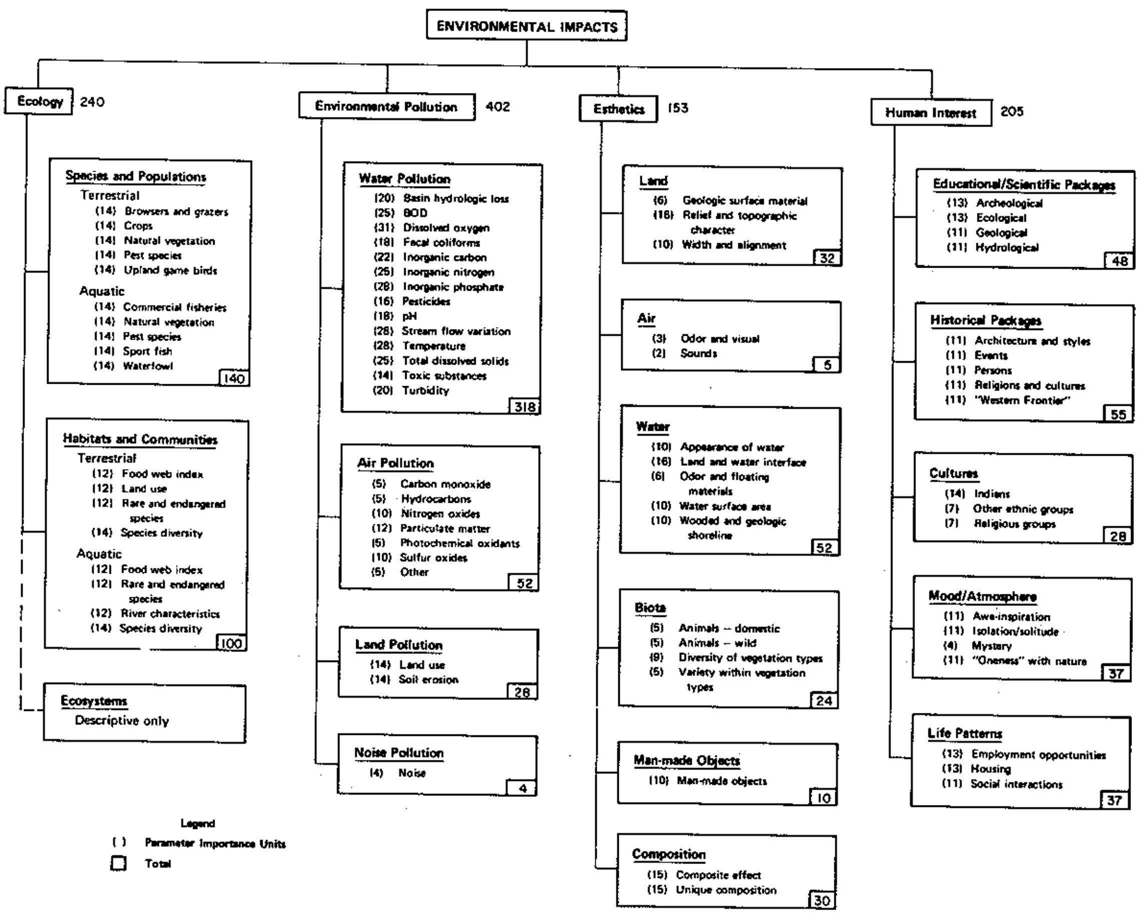


Figure 1. Battelle Environmental Evaluation System. Numbers in parentheses are parameter importance units. Numbers enclosed in boxes represent the total

For each of the environmental parameters, measurement techniques are described.

One thousand importance units, called Parameter Importance Units (PIU) are allocated among the sixty-six environmental parameters. Predictions of "with" and "without" conditions are made, although few predictive techniques are included in this report. The "with" and "without" predictions are transformed into Environmental Quality Units (EQ) through the use of value functions (see Figure 2). Each value function relates measurement of a parameter to an environmental quality index from 0.0 to 1.0.

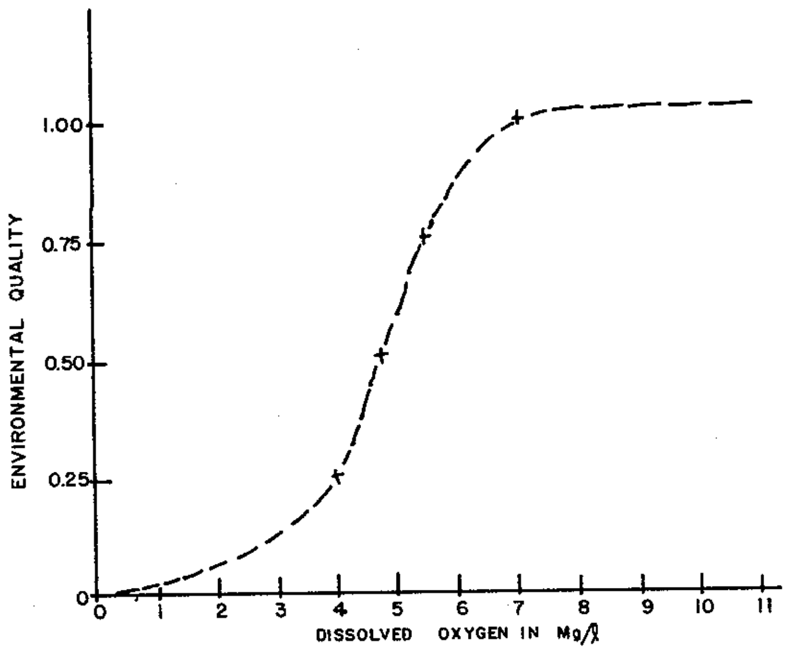


Figure 2. Example of a Value Function (Dissolved Oxygen)

For each parameter, an Environmental Impact Unit (EIU) value is calculated. The EIU for a parameter is the product of its importance (PIU) and the environmental quality index (EQ) corresponding to the projected level of that parameter.

The EIU values for all parameters are summed to provide a total EIU value for the "without" condition as well as for each alternative. The impact of an alternative is calculated by subtracting the EIU of the "with" condition from the EIU of the "without" condition.

3. Applicability:

The EES provides a weighting-scaling approach to the Appraisal of

Impacts (Evaluation of Effects). The EIU values for specific parameters or environmental categories for the alternatives considered may provide the information necessary for the trade-off analysis. This information may also be used in modifying alternative plans in successive iterations.

4. Advantages and Disadvantages:

An advantage of EES is that it is a quantitative, systematic technique which displays the differences in alternatives under consideration relative to environmental quality. EES provides a method for expressing impacts of a project in commensurate units, EIUs.

5. Previous Uses:

EES was field tested on a Bureau of Reclamation reservoir project, the Oneida Narrows segment of the Bear River Project, Utah, Idaho, and Wyoming. A summary of this field test is included in the reference.

The Fort Worth District (CE) by contract applied EES to the Aubrey Lake project. Because some of the parameters within EES are only applicable to more western portions of the United States, the usefulness of EES for evaluating lake projects in north central Texas was limited.

Although well known, EES has had limited use. This is primarily due to what some critics view as arbitrary and subjective assignment of weights and value functions.

6. Source/Contact:

Dr. Norbert Dee, Battelle-Southern Operations, 101 Marietta Towers - Suite 3313, Atlanta, Ga. 30303

Reference: Dee, Norbert et al. 1972. "An Environmental Evaluation System for Water Resources Planning," Water Resources Research, Vol 19, No. 3, pp 523-534.

1. Name:

Eckenrode, Robert T. 1965. "Weighting Multiple Criteria," Management Science, Vol 12, No. 3, pp 180-192.

2. Description:

Six methods for collecting the judgments of experts concerning the relative value of sets of criteria were compared for their reliability and time efficiency. The methods were ranking, rating, three versions of paired comparisons, and a method of successive comparisons. The judgment situations used were concerned with the design of a specific air defense system, a general air defense system, and with selecting a personnel subsystem manager for a development program. In each of these three situations six criteria were comparatively evaluated by the judges. The results of these experiments showed that there were no significant differences in the sets of criterion weights derived from collecting the judgment data by any of the methods, but that ranking was by far the most efficient method. A fourth experiment was conducted to develop baseline data on the time required to make comparative judgments versus number of items to be judged, by the ranking method and by the simplest paired comparisons method. Ranking is increasingly more efficient than paired comparisons as the number of items to be judged increases from 6 to 30.

3. Applicability:

This somewhat dated reference provides information related to methods used to derive weights and in evaluation. The methods presented could be used to develop the weights used in the Appraisal of Effects (Evaluation of Effects step) or for developing weights to be used in weighting-scaling evaluation techniques.

4. Advantages and Disadvantages:

The comparison of weighting techniques presented by this article allows determination of the most appropriate technique for a user's application. Though this article is dated, the weighting methods presented are those in current use.

5. Previous Uses:

6. Source/Contact:

1. Name:

Ellis, Scott L. et al. 1977. "Guide to Land Cover and Use Classification Systems Employed by Western Governmental Agencies," FWS/OBS-77/05, Ecology Consultants, Inc., Fort Collins, Colo. (Prepared for Western Energy and Land Use Team, Office of Biological Services, Fish and Wildlife Service, Fort Collins, Colo.)

2. Description:

This guide summarizes seventy-five classification systems used by agencies responsible for natural resource management. The classification systems are primarily for wildlife, land use, soils, and terrestrial vegetation. Summary information on systems classifies them on a multiregional or regional basis. Classification systems which are compatible with remote sensing data and computer use are indicated.

The following information for each classification system is summarized:

a. Documentation reference.

b. Contact in agency utilizing the system.

c. Stated objectives for the system.

d. Legal and institutional background of the system, which may include the stage of system development (length of application), authorization for its development and implementation, and antecedent systems.

e. Description of the system nomenclature and structure. Information is provided when possible on the data bases required to implement the classification system.

f. Products produced using the system, e.g., ecoregion maps, vegetation maps, maps showing stream ratings.

g. Related systems are referenced which are supportive or ancillary to the system.

3. Applicability:

The classification systems included in this guide are applicable to a number of planning activities. Use of these classification systems could assist in the Inventory and Forecasting of resource conditions within the planning area.

4. <u>Advantages and Disadvantages</u>:

Each system has its specific advantages and disadvantages. The limitations of each system are included in the summary.

5. <u>Previous Uses</u>:

The system summaries contain previous applications of each of the systems.

6. <u>Source/Contact</u>:

1. Name:

Fischer, David W. and Davies, Gordon S. 1973. "An Approach to Assessing Environmental Impacts," Journal of Environmental Management, Vol 1, No. 3, pp 207-227.

2. Description:

This technique utilizes a series of three matrices to (a) describe baseline conditions, (b) determine impacts on important environmental elements, and (c) compare impacts among project alternatives. The information displayed in the matrices is the result of the consensus required of planning team members. Rather than trying to include all possible environmental impacts and interactions, the thrust is to identify through consensus the significant interactions and effects. The initial matrix, the Environmental Baseline Evaluation (Table 1) is a display of environmental elements to be considered. The elements are scaled from 1 to 5 for the following parameters:

Identification	Evaluation		
Environmental elements/units	Scale of importance 1 2 3 4 5 low high	Scale of present condition 1 2 3 4 5 low high	Scale of management 1 2 3 4 5 low high
Biological:			
flora			
fauna			
ecological relationships			
Physical-chemical:			
atmosphere			
water			
earth			
Cultural:			
households			
communities			
economy			
communications			
Biocultural linkages/units			
resources			
recreation			
conservation			

Table 1. Environmental Baseline Evaluation

a. Importance.

b. Evaluation of present condition.

c. Susceptibility to management.

The linkages between each environmental element and groups of elements are considered under the biocultural linkages/units category. The list of environmental elements is determined by the planning team. The scale of importance is a weighting determined by the planning team on a 1 to 5 scale.

The judgments of the planning team on the existing quality of the environmental elements are similarly transformed to the 1 to 5 scale.

The last phase of baseline evaluation comprises a scale indicating the estimated management costs for maintaining and restoring important environmental elements. Elements and units which are rated as both being important and having a high management rating will be part of the feasibility process in the final matrix. Environmental elements and their combined linkages (biocultural units) receiving an importance rating of 4 or 5 will be carried forward to the next matrix.

The second matrix, the Environmental Compatibility Matrix (Table 2),

INTRODUCED ACTIVITIES / EXISTING ENVIRONMENT	Manufacturing	Commerce	Residence	Agriculture	Recreation	Energy	Transportation	Extractive	Water	Waste disposal	Education	Conservation
BIOLOGICAL												
PHYSICAL-CHEMICAL												
CULTURAL												
BIOCULTURAL												

Table 2. Environmental Compatibility Matrix

takes the important environmental elements identified in the baseline evaluation as input and relates those elements to the main project activity or the project and induced or ancillary activities stemming from the main project. This is in contrast with other interaction matrix approaches which attempt to identify all possible interactions and secondary impacts. Use of the Environmental Compatibility Matrix requires the determination of index values to be placed in the applicable individual cells. The impact index seeks to incorporate (a) the nature of the impact by assigning positive (+) index numbers to beneficial impacts and negative (-) index numbers to negative impacts, (b) the magnitude of impact on a range of 1 (low) to 5 (high), and (c) relative short- and long-term impacts indicated by the suffix L or S. Thus, the Environmental Compatibility Matrix summarizes the nature, magnitude, and timeliness of impacts on the important environmental elements identified in the baseline environmental evaluation. After the completion of this matrix analysis, those impacts which have values of ±4 or ±5 are carried forward to the third matrix, the Decision Matrix.

The third matrix, the Decision Matrix (Table 3), seeks to assemble

ALTERNATIVES / DECISION CRITERIA	NO PROJECT (BASELINE)	STRUCTURAL ALTERNATIVES (1 . . . n)	NON-STRUCTURAL ALTERNATIVES (1 . . . n)	LOCATIONAL ALTERNATIVES (1 . . . n)	COMMENTS
Ecological					
Physical-Chemical					
Cultural					
Biocultural					
Additional:					
Incidence					
Access					
Uncertainty					
Compensation					
Management					
Controls					

Table 3. The Environmental Decision Matrix

all the necessary information for evaluating impacts of project alternatives. The Decision Matrix compares the impacts on the important elements identified in the Environmental Baseline Evaluation by considering those impacts on important elements which were rated as ± 4 or ± 5. In addition to the important elements identified in the Environmental Baseline Evaluation, additional criteria may be evaluated for each of the alternatives. Such additional criteria may include incidence of cost and benefits, certainty of impact, and management controls necessary to implement the alternatives.

3. Applicability:

The series of matrices is appropriate for use in displaying and tracing the decisions which are made by members of the planning team. The first matrix, the Environmental Baseline Evaluation, is appropriate for use in the Specification of Problems and Opportunities and Inventory and Forecast Conditions steps. The second matrix, the Environmental Compatibility Matrix, may be used in Evaluation of Effects for Assessment and Appraisal of effects or impacts. The Decision Matrix may be used to document the evaluation processes in the Comparison of Alternate Plans and the Plan Selection steps.

4. Advantages and Disadvantages:

This technique's chief advantage is as a succinct summary and display tool for decisions and evaluations made by the planning team. A disadvantage is that scaling on only a 5-point scale may mask significant differences in impacts. Completion of the matrices is dependent on consensus of an interdisciplinary team, thus would not be effective where difficulties in interdisciplinary coordination cannot be overcome.

5. Previous Uses:

Previous uses are not documented.

6. Source/Contact:

1. Name:

Galloway, Gerald E. 1978. "Assessing Man's Impacts on Wetlands," UNC-WRRI-78-136, Water Resources Research Institute, University of North Carolina, Raleigh, N. Car. (Available from NTIS, Defense Documentation Center; accession no: ADA 094652).

2. Description:

This report presents the Wetlands Evaluation System (WES), a weighting-scaling approach to the evaluation of wetland impacts. Introductory sections of the report review a range of evaluation methods, e.g., matrices, hierarchical weighting-scaling evaluation schemes, and graphic models. The report concludes that "the utility of the system rests with the ability of the decisionmaker to assess the relative weights of the various interfaces." WES is an attempt to draw the best features of the evaluation techniques into a method that is usable today. WES takes advantage of computer capability in display of evaluation output by computer printout and graphic display.

Evaluation of impacts is based on the changes in the values of indicators of wetland quality caused by a project. WES includes the following nine quality indicators to be used in evaluation.

a. Endangered species.

b. Fishery and other aquatic ecosystems.

c. Wildlife and other terrestrial ecosystems.

d. Waterfowl.

e. Uniqueness.

f. Appearance.

g. Natural protection.

h. Life-cycle support.

i. Historical-cultural.

WES was developed for evaluation of all wetlands within a basin. To implement WES, the basin is divided into sub-basins and sub-basins are divided into relatively homogeneous areas. Rather than evaluating each wetland area for all nine indicators, the planning team determines which of the six indicators best represent the wetland under study. The indicators are evaluated on a 1-10 scale. Ten represents the highest environmental quality or quantity of the indicator being assessed, one the lowest quality or quantity. The base value, i.e. the 1-10 quality rating, is used as the basis for projecting impacts on the indicators. Impacts are projected by indicating the percentage change expected in the base value as a result of the primary and secondary effects of a project. The planning team projects the probability of the changes to indicator values as a result of a project.

WES recommends evaluation be done by an interdisciplinary team in addition to a group of public representatives outside the agency. These two groups are utilized so that the professional planning team will make the technical judgments and the public group will make the social value judgments, i.e., assign the weights to the indicators. The determination of relative weights is made after the group has been briefed by the planning team on the reasons why the six indicators being used were chosen. Indicator weights are determined for each sub-basin, estuary, or sector. If conditions within a sub-basin vary considerably, weights may be assigned on an area-by-area basis.

For evaluation of impact, the planning team projects impacts on the indicators as a percentage change to the indicator values, that is, the 1-10 base value. In addition, the probability of the impact occurring is also estimated. The various pieces of information about the wetland value indicators are assimilated.

For each indicator being evaluated, a value (V) is computed as the product of the following:

$$V = (W)(C)(P)(I)(A)$$

where

V = value of wetland area (in EQ points)

W = relative weight of an indicator

C = change in wetland value (projected impact) or changes

P = probability of occurrence of event causing change

I = indicator base value (1-10)

A = acreage of wetland

The computed values V for the indicators are summed to give the total value of the wetland.

The WES analysis of impact entails computing the change in base value for each of the indicators for the "with" and "without" project cases in addition to values for base conditions. Baseline (called AREA BASE VALUE) without project and with project values are computed based on the above formula. The percentage change from the AREA BASE VALUE is computed for the "with" and "without" case for each area. The impacts within a sub-basin are aggregated to yield a sub-basin value change.

After the changes to areas have been assessed, WES requires the evaluators to determine the cumulative impact of the changes. The interdependence of adjacent or contiguous areas requires consideration of how area changes affect other areas. The areas within a sub-basin are considered together to determine if the indicator values should be adjusted to reflect cumulative effects.

Although the indicators are described, the report does not set out the specific elements or characteristics of the indicators which are to be taken into account for evaluation. Use of WES is highly dependent on the professional judgment and experience of the planning team to determine the values for the indicators. As WES states, "The evaluation is a judgment call, but a call by individuals who are familiar with the diversity and value of wetland features throughout the area and who know that some of the wetlands are of high value and others of only marginal value." It is anticipated that existing detailed studies and other "hard" information may be used for the evaluation.

The WES analysis is computed with use of a computer program written by the author in PL/1 language. The output of the analysis is graphically displayed using programs such as CHLFORM, SYMAP, and SYMU, available from Harvard University, Laboratory for Computer Graphics and Spatial Analysis. Use of these graphics programs with digitized data allows the production of maps illustrating how wetland areas will be impacted by showing percentage of change in value from base conditions.

3. Applicability:

WES was developed to be utilized as a "judgment tool" for Appraisal and Assessment of wetland impacts. As such, the output from WES provides a weighted evaluation of the impact on indicators of wetland environmental quality. The WES system could be used in the evaluation task in each stage of planning taking advantage of increasingly detailed information. Used prior to each new iteration, WES could assist in identifying wetland areas where modification would clearly be unacceptable.

Due to its heavy dependence on professional expertise, WES could be utilized very early in planning when there is little detailed information on the study area.

4. Advantages and Disadvantages:

Evaluation of wetlands using WES is a systematic, tractable method to determine the differences in alternatives under consideration. Because of its dependency on the expertise of the evaluation team and the requirement of consensus on judgments, the results of the WES analysis may vary as there are changes in the factors considered for evaluation of the indicators, and changes in composition of the planning team and public representatives.

5. Previous Uses:

Previous uses have not been documented.

6. Source/Contact:

Col. G. E. Galloway, Jr., Department of Geography and Computer Science, U. S. Military Academy, West Point, N.Y. 10996; Phone: Commercial (914) 938-2301, Autovon 688-2301.

See also: Hansen, William J. et al. "Wetland Values-Contributions to Environmental Quality or to National Economic Development?," in Estuarine Perspectives, Kennedy, Victor E. Ed., Proceedings of the Fifth Biennial International Estuarine Conference, Jekyll Island, Ga. 7-12 October 1979.

This paper reviews the evaluation process set out in WES and compares it with that of "Wetland Values: Concepts and Methods for Wetlands Evaluation," Institute for Water Resources (1979) and judgment analysis procedures by Hammond and Adelman (1976).

1. Name:

Golden, Jack et al. 1979. Environmental Impact Data Book, Ann Arbor Science, Ann Arbor, Mich.

2. Description:

The text was developed to serve as a ready reference for the background information and data, e.g. water quality standards, that are commonly required-use data sources for the major areas relating to environmental analysis. The guide cites relevant sources for each topic utilizing the Federal Register, environmental law texts and court decision papers, technical papers, related environmental textbooks, and government documents.

The guide contains 14 major sections. The major sections and descriptions of their contents are as follows:

a. Techniques and methodologies for use in the assessment process: Approximately 60 environmental assessment methods are described, including checklists, benefit/cost analysis, demand level, fuzzy sets, mapping, matrices, networks, and simulation.

b. Data bases: Describes a variety of data bases maintained by government agencies, trade associations, industries, and foundations, which are useful in establishing environmental baselines and for use in forecasting.

c. Models: Describes models for energy, noise, cooling power plumes, transportation, thermal addition, water quality, and air quality.

d. Legal framework: Describes the jurisdictional and regulatory powers of those Federal agencies involved with the NEPA Process and related environmental legislation.

e. Air quality: Provides air quality standards; emission factors by source; classification of air quality control regions; standards of performance by source category; and mean morning and afternoon mixing heights maps.

f. Water resources: Provides information on the type of water quality data available from the STORET data base; the Federal agencies that collect and store water quality/quantity data; list of methods and techniques for gathering water related data; summary of urban water pollution sources; summaries of water quality standards and criteria; spawning reguirements of selected fishes; water requirements for public services; water requirements for energy production; and methods of measurement of aesthetics of rivers.

g. Noise: Provides information on typical noise levels during construction by type of activity; effects of noise on man; criteria for outdoor sound level analyses; effects of noise on fish and wildlife; state and Federal noise restrictions; and municipal noise ordinances.

h. Physical resources: Describes range and availability of topographical maps; soil distributions; typical soil survey data availability; soil properties classification; a method for soil loss prediction; fire data; mineral production and supplies; and earthquake risk potentials.

i. Ecosystems: Presents the concepts of biomass, communities, and ecosystems relationships; ecosystem productivity rates; impact on wildlife populations; list of endangered, threatened, or rare species in the U. S.; status of state endangered species programs; and state lists of endangered, threatened, or rare species.

j. Ecosystems: Provides examples, characterization of typical ecosystems; discussions of successional stages.

k. Toxic chemicals: Describes the legislative responsibilities of agencies in the control of chemicals; parameters for environmental assessment; toxicity of chemicals to biotic life forms; classification of chemical effects; and sporadic effects of chemicals.

l. Cultural: Describes estimated work force needs for various project types; environmental loadings from community expansion; recreation activity needs; historical significance evaluation; state historic preservation officers; and guidelines for the visual management of lands.

m. Energy: Describes energy supply and demand; energy flow patterns; energy resource supplies and sources; and future energy needs and supply projections.

n. Transportation: Describes institutional and economic transportation considerations; urban transportation characteristics; air transportation use patterns; intercity freight characteristics; transportation effects on the environment by type; energy consumption related to transportation types; and transportation related social impact analysis.

At the end of each substantive section, an extensive list of references is provided. The guide displays the most often used data in concise tables, and, by its content and structure, the guide provides the environmental planner with a comprehensive survey of the most commonly required types of data used during the impact assessment process.

3. Applicability:

The guide was recommended by several Districts as a highly useful reference. The major chapters of the guide are intended to represent the major technical aspects of environmental assessment and planning. Used as a reference guide, environmental planners should find the information useful and easily accessed during data collection, measurement of baseline conditions, and forecasting future conditions.

The guide is not intended as a handbook of preferred techniques or methodologies, nor does it provide ready-made or easy answers to the complex and difficult problems faced by environmental planners.

4. <u>Advantages and Disadvantages</u>:

One of the primary advantages of this volume is that it is written in a straightforward, easily referenced manner. Most of the information is described in tabular form and is accompanied by capsule summaries.

Information that is most frequently required is organized in such a manner as to be readily accessible in one volume. As a consequence, this reduces the amount of time required to locate important information, which would otherwise be found in numerous sources.

Despite its time-savings utility, the reference suffers from one primary disadvantage. The user must be aware that the information contained in the reference may become outdated within a short period of time, due to new legislation, regulations, or court decisions following the volume's publication.

5. <u>Previous Uses</u>:

6. <u>Source/Contact</u>:

1. Name:

Haimes, Yacov Y., and Hall, Warren A. 1974. "Multiobjectives in Water Resource Systems Analysis: the Surrogate Worth Trade-Off Method," Water Resources Research, Vol 10, No. 4, pp 615-624.

2. Description:

This paper describes the use of surrogate worth trade-off (SWT) functions for multiobjective evaluations. The SWT functions may be used to evaluate noncommensurable objectives. The SWT functions are developed to estimate trade-offs between the objectives. The development of the functions is based on linear programming in conjunction with input from the evaluator. The SWT functions are used to identify optimal solutions to a multiobjective evaluation. Specifically, SWT analysis is used to determine trade-off ratios between objectives and to identify equivalence points, that is, the point at which improvement of one objective is equivalent, or would result in, the degradation of another objective. For water resource projects, such objectives may be maximization of conservation pool size, minimization of total costs, or improvement of fish or wildlife habitat.

The initial step in developing SWT functions is the determination of λ_{ij} values. These are the trade-off ratios between objectives. The λ_{ij} values are developed in the following way. A set of objective functions relevant to the evaluation are developed. The minimum value of each function is determined. If the objective is minimization of costs, the minimum value would be 0. One of the objective functions is taken to be the primary objective $f_i(X)$ to be minimized. The other objectives are used as constraining functions. The multiobjective problem is formulated as follows:

$$\min_X f_1(X)$$

Subject to

$$f_i(X) \leq \varepsilon_j \qquad j = 2, 3 \ldots, n$$

$$g_k(X) \leq 0 \qquad k = 1, 2 \ldots, m$$

when $f_1(X)$ is the primary objective function. ε_j denotes the set of objective functions, $g_k(X)$ the set of constraining functions.

Lagrange multipliers are generated from the minimization function above. The Lagrangian equation determines trade-off ratios between the primary objective $f_1(X)$ and the constraining objectives. The Lagrangian multipliers are given in the form λ_{ij}, meaning the trade-off ratio between objective i and objective j (primary objective). The

λ_{ij} values are interpreted as the number of units of $f_1(X)$ that are equated with each unit of ε_j. In other words, the value of λ_{ij} indicates the marginal benefit of the objective function $f_1(X)$ due to an additional unit of ε_j, the constraining objective. Multipliers are calculated using successive objectives as the primary objective. The λ_{ij} values are generalized to $\lambda_{ij}(\varepsilon_j)$, the trade-off function.

The trade-off function may be determined similarly by using the equation above and solved for K values of ε_2 while all other objectives are held fixed at some level ε_j^o. For each value of $f_2k(X)$, $k = 1, 2 \ldots, K$, a functional value of $\lambda_{ij}[f_iR(X)]$ is generated. A regression analysis is used to fit $X_{ij}[(f_j(X)]$ and $f_j(X)$. This regression will yield the trade-off function. If the regression is sensitive to different values of the constrained objectives, multiple regression analyses should be performed.

The λ_{ij} values determine the trade-off in terms of units of each objective. The development of surrogate work functions requires that the trade-off value be weighted. The evaluator or decisionmaker determines the desirability of the marginal trade-offs, that is, the surrogate worth of the trade-off between noncommensurable objectives. The SWT functions are developed to show the desirability of each λ_{ij} as a function of every other λ_{ij}. The derivations of the SWT functions are similar to the trade-off functions. The derivations produce surrogate worth functions W_{ij}, $i \neq j$, $i,j = 1, 2 \ldots, N$. The SWT function W_{ij} associated with the i^{th} and j^{th} objectives can be defined as follows:

$$W_{ij} > 0$$

when λ_{ij} marginal units of $f_i(X)$ are preferred over one marginal unit of $f_j(X)$, given the satisfaction of the other objectives at level ε_k^o, $k \neq i$, $k = 1, 2, \ldots n$. $W_{ij} = 0$ when λ_{ij} marginal units of $f_i(X)$ are equivalent to one marginal unit of $f_j(X)$.

$$W_{ij} < 0$$

when λ_{ij} marginal units of $f_i(X)$ are not preferred over one marginal unit of $f_j(X)$.

A surrogate value is defined for each trade-off ratio. The optimum is found at the point where all trade-off ratios are selected to make the surrogate worth functions simultaneously equal to 0 (or such other number as may be designated as the measure of an even trade).

The computational procedures for constructing the surrogate functions are similar to those used to develop the trade-off functions. One approach utilizes an ordinal scale to construct a function of λ_{ij}. The evaluator is asked when the λ_{ij} units of $f_i(X)$ are greater than, equal to, or less than one unit of $f_j(X)$ for two distinct values of λ_{ij}. A linear combination of the two answers $W_{ij}(\lambda_{ij})$ in the ordinal scale can be made. The value $\lambda_{ij} = \lambda_{ij}{}^*$ is chosen such that $W_{ij}(\lambda_{ij} = 0)$ on the line segment fitting the two values of λ_{ij}. To improve the accuracy of λ^*_{ij}, additional values can be derived from the evaluator. After the determination of all $\lambda_{ij}{}^*$ for $i, j = 1, 2 \ldots n$, the following system is solved:

$$\lambda_{ij}(X) = \lambda_{ij}{}^* \quad i,j = 1, 2 \ldots n,\ i \neq j$$

Another approach uses the constraints approach. For each $\lambda_{ij}{}^*$ determined from the surrogate worth function determined by the evaluator, there is a corresponding $f^*_j(X)$, $j = 1, 2 \ldots n$, $j \neq i$. These $f^*_j(X)$ are the value of the $f_j(X)$ function at the equality or trade-off point. The optimal vector of X^* may be found by solving the following optimization problem:

$$\min_X f_i(X)$$

subject to

$$f_i(X) \leq f^*_i(X) \qquad j = 1, 2 \ldots n$$

$$g_r(X) \leq 0 \qquad k = 1, 2 \ldots m$$

The solution to this optimization problem provides the desired X^* (rather than λ_{ij}) for each function in the total vector optimization problem.

The third approach for developing the surrogate worth function involves regression analysis. The decisionmaker is asked to compare several different values of λ_{ij} versus $f_j(X)$ and use this information for construction of a function $W_{ij}(\lambda_{ij})$. After the process is repeated for $i \neq j$, $i, j = 1, 2 \ldots n$, a transformation of $W_{ij}(\lambda_{ij})$ is performed to yield the surrogate worth function.

Using any of the three methods above, a surrogate worth function may be constructed. Using the developed function for an evaluation, one may determine:

a. Trade-off ratios between the objectives, i.e. the λ values.

b. Surrogate worth trade-off values, i.e. the desirability of the trade-offs.

c. Optimal solutions to the objective functions.

The optimal solution is determined where W values are equal to 0. At these points, improvement of one objective can be obtained only by degradation of another objective. These equivalence points may be interpreted as the values for the functions that ensure that all objectives are attained at some minimal level. The W values generated, in addition, provide solutions to the objective functions which show the range of W values for each $f(X)$. This range enables the evaluator to identify the equivalence points, i.e., $W = 0$, as well as the solutions which fall on either side of the equivalence points.

3. Applicability:

The evaluation of noncommensurable objectives is required in any water resources evaluation. The SWT approach provides a method to identify alternatives that ensure acceptable levels of the multiple objectives. The trade-off ratios and surrogate worth functions developed provide a method to determine trade-off and to judge the desirability of each trade-off in a systematic fashion. The SWT method could be utilized for the appraisal process in the Evaluation of Effects step.

4. Advantages and Disadvantages:

The advantages in using the SWT method are that it provides a quantified, systematic approach to evaluation of noncommensurable objectives. The development of the range of W values allows the evaluator to determine which alternatives attain equivalence point values. The disadvantage of using a SWT analysis is that it is time intensive, requiring the evaluator to make judgments on the value of the trade-offs between each pair of objectives. In addition, computer capability is usually required to solve the equations.

5. Previous Uses:

The SWT method was utilized to evaluate alternatives in the Virgin River Basin Study, Utah, Nevada, and Arizona.

6. Source/Contact:

Dr. Y. Y. Haimes, Systems Engineering Department, Case Western Reserve University, Cleveland, Ohio.

1. Name:

Headquarters, Department of the Army, CE. 1975. "Handbook for Environmental Impact Analysis," Pamphlet No. 200-1, Washington, D.C.

2. Description:

This handbook presents recommended procedures for use by Army personnel in the preparation and processing of environmental impact assessments (EIA) and statements (EIS) for military activities. The methodology basically consists of using an interaction matrix to identify potential impacts and generate a descriptive checklist. A checklist of representative Army actions that might have a significant environmental impact is included, and guidance is provided in the identification of impacts of Army activities in nine functional areas: construction; operation, maintenance and repair; training; mission change; real estate; procurement; industrial activities; research, development, test, and evaluation; and administration and support. Forty-six environmental attributes (assessment variables) are included in the methodology and listed in Table 1.

Table 1

Environmental Attribute Listing*

Category	No.	Attribute	No.	Attribute
Air	1	Diffusion factor	6	Carbon monoxide
	2	Particulates	7	Photochemical oxidants
	3	Sulphur oxides	8	Hazardous toxicants
	4	Hydrocarbons	9	Odor
	5	Nitrogen oxide		
Water	10	Aquifer safe yield	17	Biochemical oxygen demand
	11	Flow variations	18	Dissolved oxygen (DO)
	12	Oil	19	Dissolved solids
	13	Radioactivity	20	Nutrients
	14	Suspended solids	21	Toxic compounds
	15	Thermal pollution	22	Aquatic life
	16	Acid and alkali	23	Fecal coliform
Land	24	Erosion	26	Land use patterns
	25	Natural hazard		
Ecology	27	Large animals (wild and domestic)	31	Field crops
	28	Predatory birds	32	Threatened species
	29	Small game	33	Natural land vegetation
	30	Fish, shellfish, and water fowl	34	Aquatic plants
Sound	35	Physiological effects	38	Performance effects
	36	Psychological effects	39	Social behavior effects
	37	Communication effects		
Human	40	Life styles	42	Physiological systems
	41	Psychological needs	43	Community needs
Economic	44	Regional economic stability	46	Per capita consumption
	45	Public sector revenue		

* After U. S. Department of the Army,1975.

3. Applicability:

This handbook's chief contribution to Civil Works planning is the definition, measurement, and interpretation information on the 46 environmental attributes/variables which are primarily associated with the EQ Account. This listing of variables is referenced in the Engineer Regulation 1105-2-400 series as a useful source for determining appropriate environmental resource components for inclusion in a comprehensive resource inventory in Stage 1 planning. This set of attributes is similar to the set included in:

Jain, Ravinder K., Urban, Loyd V., and Stacey, Gary S. 1981. Environmental Impact Analysis, 2nd. Ed., Van Nostrand Reinhold, New York, N.Y.

4. Advantages and Disadvantages:

The advantage in utilizing this document is that it provides a comprehensive checklist which can be utilized in environmental analyses. However, because the report was prepared with emphasis on military activities, use for civil works projects requires adaptation of the attribute documentation to nonmilitary activities.

5. Previous Uses:

6. Source/Contact:

1. Name:

Headquarters, Department of the Army, CE. 1979. "Remote Sensing Applications Guide," Engineer Pamphlet (EP) 70-1-1, Washington, D.C.

2. Description:

The purpose of this EP is to provide technical guidance for developing effective uses of remote sensing within the Corps. The EP is designed to assist the user in:

a. Identifying, planning, and conducting remote sensing application efforts.

b. Locating relevant remote sensing imagery data, experts, and services internal and external to the Corps.

c. Acquiring an understanding of remote sensing fundamentals.

This EP was written for the express use of Corps planners who have had little or no experience with remote sensing. The discussions of the various types of remote sensing imagery and their characteristics are comprehensive, but written for the remote sensing layman.

The guide consists of three parts:

Part 1: Planning and Management Guidelines for Remote Sensing.

Part 2: Technical Guidance.

Part 3: Supporting Appendices.

Part 1, Planning and Management Guidance, has two primary functions: first, to survey the current Corps remote sensing activities from organizational, functional/disciplinary, and applications perspectives, and second, to provide a systematic approach to the planning and management of remote sensing applications, which includes a practical working guide for the assessment of technical feasibility, preliminary planning, and implementation of remote sensing data acquisition.

The approach to planning and managing a remote sensing application involves three phases. The three phases and their constituent actions and required precisions are summarized in Figures 1-3, Extended Profile Section. Figure 1 provides a flowchart for the first phase of the suggested approach -- Determination of the Technical Feasibility of Applying Remote Sensing. The primary function of phase one is to define the characteristics of the phenomena of interest, e.g., specific landforms or plant types/communities, and identify whether or not they can be effectively sensed using remote sensing techniques, as well as assessing the availability of older, usable imagery and Corps experience with the type(s) of remote sensing techniques initially selected.

Figure 2 provides a flowchart for phase two activities -- Preliminary Planning for Remote Sensing Application. The primary objective of phase two is to establish the suitability of each of the remote sensing techniques identified in phase one for satisfying project data requirements. This is accomplished through the preparation of a Preliminary Work Plan (PWP). The PWP documents specific project data requirements and compares them with candidate remote sensing techniques. The PWP becomes the basic planning tool for the remote sensing application. If, following the completion of phase two, one or more remote sensing techniques are able to provide imagery satisfactory to project needs, phase three is implemented.

Figure 3 provides a flowchart for phase three activities--Implementation of the Remote Sensing Plan. The primary objective of phase three is the organization and implementation of the final Work Plan. The Work Plan provides an overview of the total remote sensing effort and helps identify problems at the earliest possible time. During phase three the remote sensing technique selected is "flown," the data are analyzed, and final decisionmaking products are produced.

Part 2, Technical Guidance, provides planners with sufficient technical information about remote sensing techniques so that they can either prepare or evaluate remote sensing RFPs, or define the technical characteristics of imagery that are suitable for the proposed study and available from other Corps units or federal or state agencies, or the private sector. The emphasis in Part 2 is on the provision of comprehensive but nonmathematical treatments of the major topics relevant to planning, acquiring, and analyzing remotely sensed data.

a. Chapter 2 provides a basic introduction to electromagnetic energy and its sources and interactions: Special attention is given to those sources of electromagnetic energy that are potentially useful to remote sensing applications, e.g., sunlight, skylight, flares and flashes, searchlights and lasers within the optical wavelengths; the sun, terrain materials, skylight, and artificial sources within the infrared wavelengths; and sources of energy within the microwave wavelengths.

b. Chapter 3 provides a discussion of the different types of remote sensing systems available to users. Three types of remote sensing systems are considered: photographic systems, imaging scanner systems, and nonimaging devices. The section on imaging scanner systems includes optical, infrared, and microwave scanner operation. The section on nonimaging systems concerns radiometers and distance measuring devices.

c. Chapter 4 provides a brief summary of the various platforms (e.g., aircraft, satellites) available to remote sensing users:

Emphasis is placed on the form and characteristics of the platforms and the constraints imposed by the platform on the performance of remote sensing systems. The primary platforms are: ground contact platforms, airborne platforms, ballistic platforms, and waterborne platforms.

d. Chapter 5 is concerned with the types of products that result from conventional remote sensing systems, i.e., from aerial photography and nonclassified satellite imagery: A distinction is made between primary and transformed products. Primary products include photographic products, magnetic tape, and real time displays. Transformed products include photographic and magnetic tape products that are modified electronically or optically to make them easier to interpret or more compatible for producing end products. For photographic products, transformations include changes in scale, geometry, optical density and contrast, color, mosaicising, and digitizing. Procedures for scale changes, rectification, density slicing, contrast modification, image combination, edge enhancement, and filtering are discussed for digital data. Analog electronic techniques and coherent optical processing are discussed for analog data.

e. Chapter 6 provides information and guidance for planning remote sensing missions: Emphasis is placed on using the most cost-effective system that will provide the required data in a form compatible with the user's capabilities for generating the final and desired product. Special attention is given to the issues revolving around the types of sensor that can be used, temporal data acquisition planning, and methods for "flying" the mission.

f. Chapter 7 summarizes ground control, i.e., ground truth, considerations: Ground control information improves the quality of the inferences that must be made in order to interpret remote sensing products. Sources of ground control include maps, existing imagery, literature, and field data collection. In designing a ground control program the remote sensing user must determine exactly what must be known in order to make a reliable interpretation. This results in the selection of specific factors, or indicators, that assist the remote sensing user. These factors may include such things as channel geometry, watershed characteristics, water characteristics, vegetation characteristics, or soil characteristics.

One of the most important ground control considerations is the user's ability to relate positions on the ground to positions on the imagery. To accomplish this, especially in large areas of similar features, the user may resort to the placement of target arrays that can be used for aerotriangulation. Since all imagery is a distortion of the real world, ground control becomes an important component in the creation of usable end products, and each type of remote sensing requires specific types of ground control.

g. Chapter 8 outlines methods for extracting information from remote sensor imagery and postinterpretation processing and display of the data to achieve the desired end products.

Part 3, Supporting Appendices, provide:

a. A summary of Federal, state, and Corps offices that have imagery available upon request (Appendix A).

b. A summary of civilian agencies and military units, state agencies, academic institutions, and private companies that have remote sensing data acquisition capabilities (Appendix B).

c. A tabulation of available remote sensors and their general characteristics (Appendix C).

d. A user's directory for past Corps of Engineers remote sensing applications (Appendix D).

e. Selected information and tools to assist in the planning and management of remote sensing programs (Appendix E): Among these tools is the Photographic Systems Simulation Model (PSSM), a computer program designed to provide the user with an efficient method for evaluating how well a number of aerial film-filter combinations will perform for a given data acquisition problem. It predicts the image optical density contrast that would occur between a selected feature and its background based on their reflectance properties, the atmosphere, sun angle, and film, filter, and camera characteristics.

f. Listings of image processing and interpretation services, image processing hardware systems, and image processing software systems (Appendix F).

g. A bibliography of sources of basic information on remote sensing (Appendix G).

3. Applicability:

This EP provides a comprehensive review of the use of remote sensing within the Corps. When the need for a particular type of information has been identified, this EP can be used to:

a. Assist in determining if remote sensing may be used to acquire the information.

b. Determine if remote sensing data exist and/or are available.

c. Assist in preparation of the scope of work for a remote sensing RFP and in the evaluation of submitted RFPs.

4. Advantages and Disadvantages:

If older imagery is either unavailable or not acceptable for particular project purposes, this EP outlines a systematic approach to the development of remote sensing mission profiles. The data in this guide, coupled with the assistance of knowledgeable remote sensing specialists, can provide the potential remote sensing user with sufficient background to make the required management and planning decisions regarding the use of remotely sensed data.

5. Previous Uses:

Appendix D (Part 3) provides an in-depth survey of remote sensing applications by the Corps of Engineers. This appendix is cross-referenced by organization, application, function, and discipline. In addition, throughout each part there are accompanying referential citations.

6. Source/Contact:

Dr. L. E. Link, Jr., USAE WESESD, P. O. Box 631, Vicksburg, MS 39180. FTS 542-2606 or (601) 634-2606

1. Name:

Hendricks, David W. and DeHaan, Roger W. 1975. "Input-Output Modeling in Water Resources System Planning," Environmental Engineering Technical Report No. 3, Department of Civil Engineering, Colorado State University, Fort Collins, Colo.

2. Description:

This report describes the application of input-output analysis to water resource planning. Principles of input-output analysis were developed by Wassely W. Leontief to model the U. S. economic system. The principles developed by Leontief for analyzing the economic system are applied to the analysis of water systems. Input-output (I-O) analyis is a type of systems analysis which analyzes the flow and transformation of a resource. The resource is quantified and flow must be expressed in common terms.

The system is partitioned into major sectors representing the production, distribution, transportation, and consumption of resources. These sectors receive a specified flow (inflow) and have a specified outflow of the resource. The I-O model is represented as a matrix of sectors, one axis being origin of the resource, the other being the destination. The I-O model can represent any system that contains both production and utilization of a particular resource. The flow between sectors is represented by the intersection of rows and columns in the matrix.

To organize the analysis, the diverse parts of the system are aggregated into a workable number of relatively homogeneous sectors. The sectors are subdivided into subsectors. The subsector organization should be capable of describing all transfers of resources which occur within the system.

The report described the development of an I-O analysis for the South Platte River Basin, Colorado. The basin's water resources had been highly developed for industrial, municipal, and agricultural (primarily irrigation) purposes. These three purposes formed the use sectors. The following aggregation scheme was used for the sector categories and subcategories.

Sector Category	Sector Subcategory
Exogenous Inputs	Precipitation Other basins Future development

Sector Category	Sector Subcategory
Intermediate Sectors	Tributary streams Transmountain diversion facilities Lakes Canals and pipelines Future development
Use Sectors	Municipal Industrial Agricultural
Natural Use Sectors	Forest and grasslands Open waters
Final Destinations	Surface water outflows Groundwater outflow Consumptive uses Losses

Each subcategory is further subdivided to include its constituent parts. For instance, the municipal use subcategory contained all the municipalities which divert water for municipal purposes.

The subcategories and constituent parts are used to form an I-O matrix. Both axes of the matrix contain the constituent parts. By convention, the rows of the matrix represent the supply or origin of resources and the columns are the demand or destination of the resources. The exogenous inputs are listed only in the supply rows and the final destinations are listed only in the destination columns.

After the matrix is developed, the data necessary to quantify the matrix interactions were compiled. This required taking the available hydrologic and water consumption data and partitioning the available supplies of water among the users or destinations. The water produced by each of the suppliers subcategory is allocated among the destination subcategories to which water is supplied. Reading down a column, it is possible to determine how each destination meets its demand for water, that is, what are the supplying sources. Reading across a row, one may determine how each supply of water is distributed.

After the matrix is completed, matrix coefficients are calculated. For the South Platte Study two coefficients were calculated for each cell in the matrix, i.e. supply and demand coefficients. The supply coefficient is defined as the ratio between the number in a matrix cell and the sum of that cell's row. The supply coefficient expresses the relative amount of water that is supplied from each source. Similarly, the demand coefficient is defined as the ratio of the number in a cell to the total of that cell's column. The demand coefficient shows the relative amount of water that is consumed from a sector's supplies.

These coefficients were used because they have special relevance to this particular study. It is possible to develop coefficients which are meaningful for each specific study.

From the completed matrix, three I-O indexes were developed. These indexes are analogous to the gross national product, gross domestic output, and value added indexes developed from economic I-O analyses. The first index, the total utilized water, is the total amount of water transferred to individual human entities which put water to beneficial use through the exercise of water rights. The second index, total system water, is the sum of the water transfers in the use sectors and in the intermediate sectors. The last index, consumptive use and losses, represents the difference between water entering and leaving a given use entity. To parallel an economic I-O matrix, this may be thought of as a negative value added.

The development of an I-O matrix provides a quantitative analysis of a system. The interrelationships and interdependencies of the system are identified. The I-O analysis provides a baseline description of an existing system; however, as in the South Platte case, anticipated developments may be included in the matrix.

3. Applicability:

I-O analysis provides a quantified method for systems analysis. The development of the I-O matrix is a tractable way to specify the interrelationships of a system. An I-O model could be used in the Inventory, Forecast, and Analysis step to analyze the flow of resources. The model could further be used to project and trace the impact of changes caused by anticipated alternatives.

4. Advantages and Disadvantages:

The advantages of using an I-O model are that it is a holistic and quantified method to describe a system. The disadvantages are that fully quantified data may not always be available for some aspects of a system. In addition, the requirement that all sector transfers be expressed in the same units limits the usefulness of the method by being oriented to single resource flows.

5. Previous Uses:

The report documents the development of an I-O analysis for the South Platte River, Colorado.

6. Source/Contact:

Dr. David W. Hendricks, Department of Civil Engineering, Colorado State University, Fort Collins, Colo.

1. Name:

Holling, C. S. 1978. Adaptive Environmental Assessment and Management, John Wiley and Sons, Chichester, England.

2. Description:

The approach to environmental impact assessment described by Holling centers around the development of a predictive model of the environmental system under consideration. The assessment is carried out by using a series of workshops to develop a system model and to apply it to alternative projects or policies.

A workshop format is utilized to bring together the personnel with the expertise needed for developing the assessment. A so-called "core group," consisting of environmental specialists or planners, carries out the data collection and day-to-day aspects of the assessment.

In the initial workshop, the impact categories are classified, key information needs defined, and a crude working model is developed. After the workshops, the core groups collect the information required. Subsequent workshops are used to further define management objectives, refine the model, and identify data needs. Each workshop is followed by a period of consolidation in which data are collected and assembled. The product of this process is a report which makes recommendations based on the application of the model to the alternatives under consideration.

The workshop participants consist of the core group plus administrative or management personnel responsible for implementing the chosen alternative, specialists in disciplines relevant to the problem or project (e.g., biologists, economists, or hydrologists), and methodologists, such as system analysts or computer specialists. Such a mix of participants is desirable so that the system model developed is acceptable to decisionmakers and planners alike. In addition, by utilizing available expertise in development of the systems model, the goal is to make the systems model comprehensive without becoming so complex as to be cumbersome.

The modelling technique used should fit the characteristics of the system under consideration. A highly quantitative modelling technique would have little usefulness if only qualitative data were available. The expense of computer modelling would be wasted if a qualitative graphical representation adequately describes all important elements in the system. The particular modelling techniques chosen for use, whether simulation models, matrix, or other techniques, will depend on such characteristics as an understanding of system components, system dynamics, or the data requirements for the modelling technique.

The approach to impact assessment is termed adaptive because it seeks to use the technical expertise of relevant disciplines in conjunction with the managerial experience of administrators to develop a predictive model which assesses the impacts of alternatives. This approach to impact assessment has been utilized to assess a variety of alternative development and management strategies.

3. Applicability:

This approach to environmental assessment, that is, the use of a series of workshops for model development and impact prediction, could improve the impact assessment of many Corps studies. Many Corps studies utilize the services of consultants and others with specialized knowledge in particular aspects of a study. Having these non-Corps personnel participate as part of the core group in the initial and subsequent workshops could possibly improve the quality of the modelling effort. By having all those involved with a study participate in a model development workshop, the model and the data collection efforts to support it are more likely to focus on the most important aspects or resources than if the core group worked independently. This can result in the saving of resources in the collection of only data that are relevant to the systems model.

4. Advantages and Disadvantages:

The advantages in using this approach are that the impact assessment process can conceivably be improved by the workshop to develop and refine the systems model. The expertise of the systems analyst, computer specialists, the various disciplines of the core group, and the management personnel is used to develop a comprehensive system model, define management objectives, and identify data needs. As data are collected and analyzed, the core group further refines the model. The interactions of the workshops can speed up the assessment process by focusing on the important or critical parts of the model.

A disadvantage of such an approach is managing the logistics of the workshop.

5. Previous Uses:

The Detroit District utilized this adaptive approach in the preparation of the Final Survey Study for Great Lakes and St. Lawrence Seaway Navigation Season Extension.

6. Source/Contact:

1. Name:

Jain, Ravinder K., Urban, Loyd V., and Stacey, Gary S. 1981. Environmental Impact Analysis, 2nd Ed., Van Nostrand Reinhold, New York, N.Y.

2. Description:

This text is an up-to-date guide to the environmental impact assessment process, incorporating the 1978 CEQ NEPA Regulations and other developments which occurred subsequent to publication of the first edition. Introductory chapters explain the philosophical and political basis of NEPA as well as detailing the procedural requirements of the Act. Various types of impact assessment methodologies are explained and nineteen specific methodologies are reviewed in depth. Special issues in impact assessment are addressed, including public participation, the role of economic impact analysis in environmental assessment, interdisciplinary planning, and energy considerations in impact analysis. A generalized approach to impact assessment is presented in Figure 1.

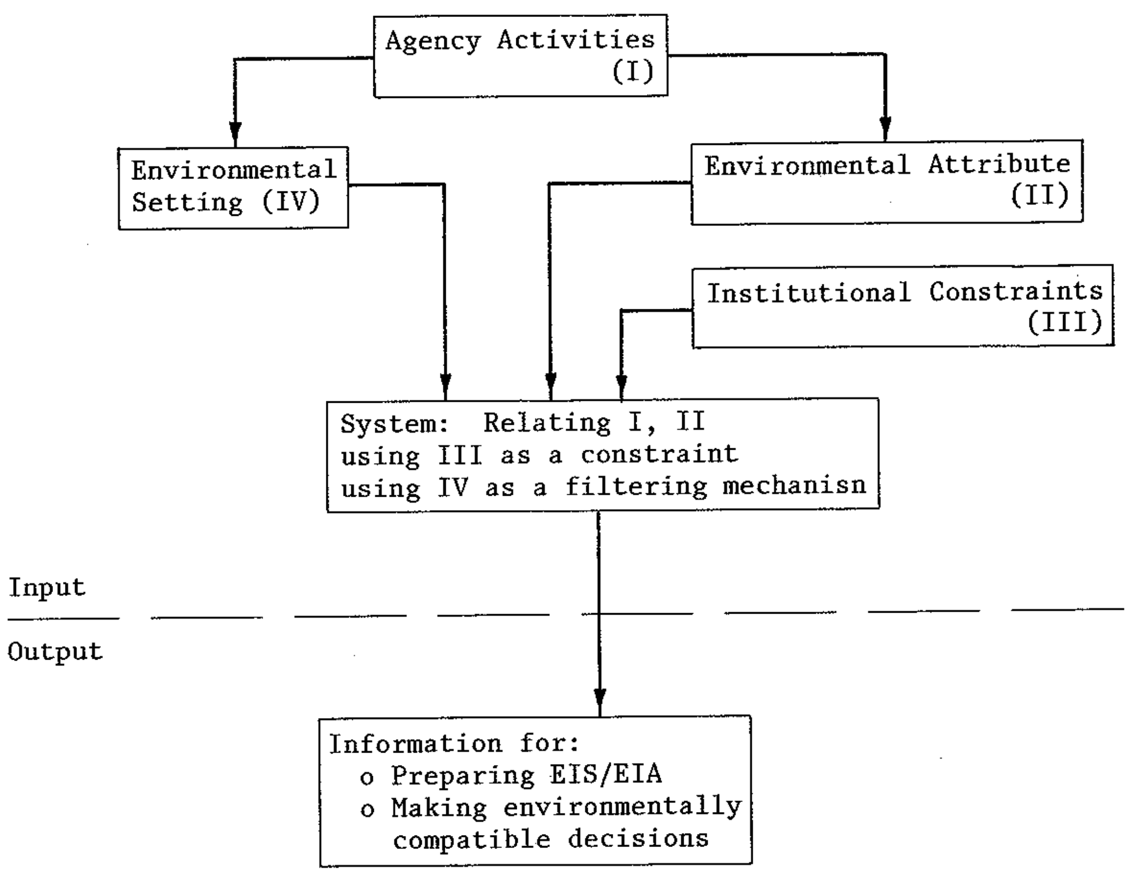


Figure 1. Generalized Approach to Impact Analysis

Central to this approach to impact assessment is a set of environmental elements known as environmental attributes. Forty-nine attributes are utilized to represent the various aspects of the environment. This set of attibutes includes the forty-six listed in Table 1, HQDA 1975 profile, in addition to three attributes included in a Resources category (Fuel Resources, Nonfuel Resources, and Aesthetics). For each of the attributes information is included to enable the user to determine if it will be affected by an agency action, and information is presented on the variables used to measure the attribute, impact measurement of variables, and the evaluation and interpretation of impacts. Mitigation of impacts and secondary impacts are also discussed. Examples of information included for each of the attributes are included in the Extended Profile Section. The generalized approach to assessment seeks to delineate impacts by relating agency activities to changes in environmental attributes from the baseline environmental setting, considering institutional constraints (such as effluent standards or air emission standards). A system to relate agency actions, the environmental setting, potentially affected environmental attributes, and institutional constraints is then utilized to predict and analyze the potential environmental impacts of an action. Little guidance is given on the choice or characteristics of such a system except to indicate it "could be just as simple as a thinking process, a manual storage and manipuliation system, or a computer-aided system."

Guidelines are presented for the review of environmental impact statements (EISs). EISs are screened on the basis of the range of impacts of the projects. Small-impact projects receive less intensive review than high-impact projects. Examples of the type of questions which should be addressed in an EIS review are included for three ranges or magnitudes of project impacts.

3. Applicability:

This text provides an up-to-date reference on the environmental assessment process. The guidelines for review of EISs could be utilized in the interagency review process. The chief contribution of this reference is the definition, measurement, interpretation, and evaluation information on the forty-nine attributes. The attribute information could be utilized as a checklist in the assessment process for all stages of planning. The set of attributes is a useful source for determining appropriate environmental components for inclusion in a resource inventory in early planning.

The information included for each of the attributes would be useful in the Evaluation of Effects to identify and trace impacts and measure impacts. This approach to impact assessment would be applicable to all types of CE projects.

4. Advantages and Disadvantages:

While the forty-nine attributes cover many aspects of the environment, the authors indicate the attributes are intended to provide an overview of the nature of the potential impacts. More specific or detailed attributes or variables may be required for particular water resource projects.

5. Previous Uses:

6. Source/Contact:

Headquarters, Department of the Army, CE. 1975. "Handbook for Environmental Impact Analysis," Pamphlet No. 200-1, Washington, D.C. See HQDA 1975 Profile. This is an application of this approach to military activities.

Dr. R. K. Jain, U. S. Army Construction Engineering Research Laboratory

1. Name:

Kruzic, Pamela G. 1974. "Cross-Impact Simulation in Water Resource Planning," IWR Contract Report 74-12, U. S. Army Engineer Institute for Water Resources, Fort Belvoir, Va. (Prepared for IWR by Stanford Research Institute, Menlo Park, Calif.)

2. Description:

KSIM is a simulation procedure for structuring and analyzing relationships among broadly defined variables acting in systems. It was originally developed by Dr. Julius Kane, University of British Columbia, to allow decisionmakers to (1) accommodate a mix of hard data and intuitive judgment and (2) test alternative planning options efficiently by:

a. Exploring how a range of likely futures may shape a plan or, in turn, be subsequently modified by a plan.

b. Examining how various changes, such as in causal interactions or public preference, could affect the impacts of alternatives.

The steps in the KSIM procedure are depicted in Figure 1. The key step is to develop the cross-impact matrix which summarizes the impacts of each variable upon each other variable. The variable names or labels are listed as row and column headings of a table. A basic assumption is that when one variable changes, a second variable may be completely unaffected, or may be encouraged or inhibited. To show this, during the initial phase of KSIM the variables are assigned cross-impact values of (0) for unrelated, (+) for encouraged, or (-) for inhibited. Completing the cross-impact matrix in this way provides the initial structure for the model. More precise estimates of the levels of interactions among variables are specified by assigning numerical values to these preliminary cross-impact estimates.

KSIM combines a small group workshop procedure with a mathematical forecasting model and a computer program to generate changes over time in a few significant planning variables. The method helps to identify planning needs, develop models, and test the consequences of policy actions. The technique requires expert leadership and access to a computer. A KSIM computer program is available.

KSIM presents a mathematical means of articulating and visualizing what people sense to be the relationships among a number of interacting variables. As a simulation tool, it combines expert opinions with analytical computing techniques to analyze relationships among broadly defined variables in environmental and other systems. The technique enables a team of people to first define and structure a set of variables describing a perceived problem and, then, using an interactive computer program, to calculate and display the projected changes in the variables over time. By observing the changes and then making modifications and refinements, the team develops a model of the problem situation. With the model, individuals can test various alternatives and review and improve their understanding of the problem.

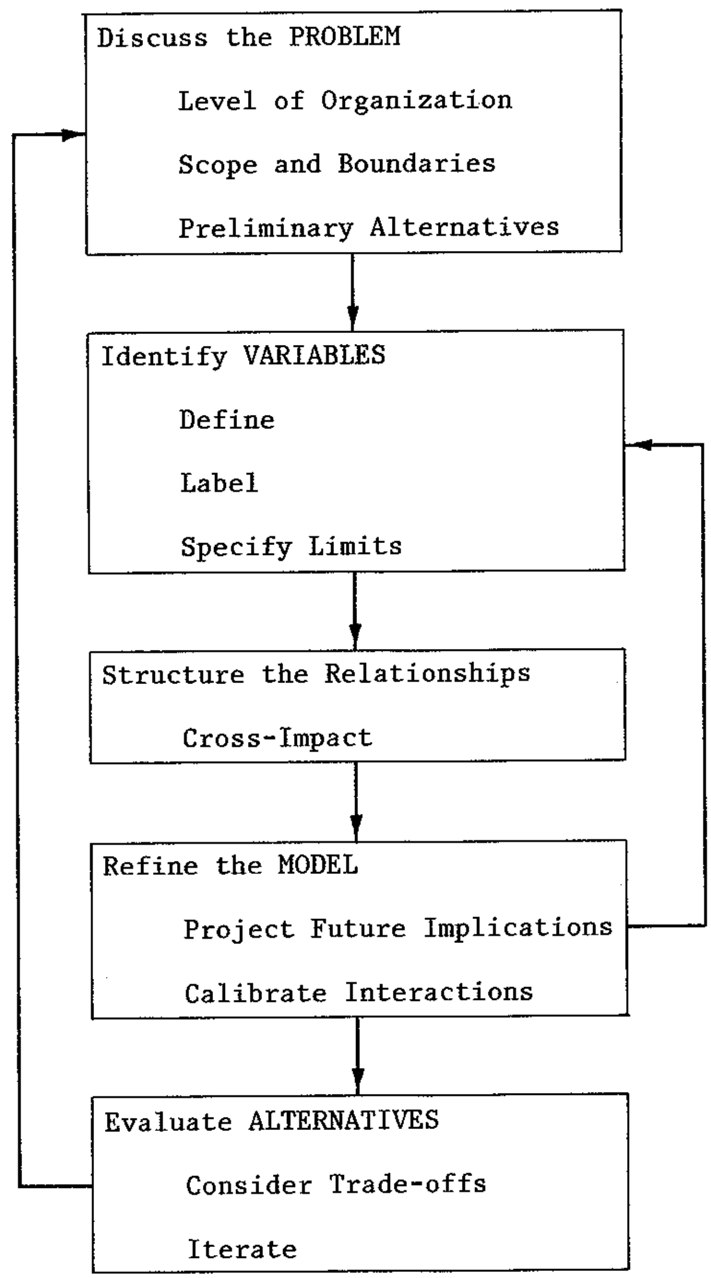


Figure 1. Steps in the Procedure

3. Applicability:

KSIM simulation assists in identifying important variables, specifying their relationship and interactions, and forecasting changes in the variables. As such, KSIM can provide a valuable tool for analyzing the water and land resources problems and opportunities. KSIM can assist in the initial steps of the planning process, i.e., Specification of Problems and Opportunities and Inventory Forecast, and Analysis of Conditions. A KSIM simulation can assist the planning team in accomplishing these two steps by systematically inventorying resources and considering the interactions of the resources. KSIM is applicable to all types of studies and stages although more quantitative modeling techniques may be more useful in later planning stages.

4. Advantages and Disadvantages:

KSIM is a quick and easy-to-use computer simulation tool when several variables are adequate to summarize essential system dynamics. KSIM gives a good indication of qualitative dynamics in the system being analyzed and can serve as an excellent preparation for more intensive, quantitative, or expensive forecasting efforts. It is useful as a heuristic modeling system and to foster integration among members of an interdisciplinary team.

KSIM does not produce reliable quantitative projections and will not handle complex systems with large numbers of variables. It is best to use it in conjunction with other more rigorous techniques.

5. Previous Uses:

This report illustrates use of KSIM to assess the effects of water resources development on an urban area.

The KSIM team consisted of eight members, who contributed the following disciplines, affiliations, and points of view:

Urban Study Manager	District Planner
Resource Geographer	Division Planner
Urban Planner	District Planner
Urban Economist	District Planner
Civil Engineer	Local Planning Representative
Regional Economist	Local Planning Representative

Water Resource Planner	Research Manager
Systems Analyst	KSIM Coordinator

Once they developed a model that generally satisfied them as a most probable future, the team members altered it to reflect three alternative futures--increased residential density from rapid transit, limited residential density accompanied by a greater range of socioeconomic opportunities, and long-term energy shortage.

6. Source/Contact:

For a copy of the program contact Julius Kane, Department of Mathematical Ecology, University of British Columbia.

Kane, Julius, Vertinski, Ivan, and Thomson, William. 1973. "KSIM: A Methodology for Interactive Resource Policy Simulation," Water Resources Research, Vol 9, No. 1, pp 65-79.

Rogers, Steven D. 1978. "KSIM," Appendix E, in The Use of Structural Modeling for Technology Assessment, Vol 2, by Linstone et al. (Prepared for the National Science Foundation/RANN, Feb 1978.) See Linstone Profile.

1. Name:

Lendaris, George G. 1978. "Interpretive Structural Modeling," in Linstone, Harold A. et al. "The Use of Structural Modeling for Technology Assessment," Vol 2, Portland State University, Portland, Oreg. (Prepared for the National Science Foundation/RANN by Portland State University.)

2. Description:

Interpretive Structural Modeling (ISM) is a computer-aided process to assist groups, such as planning teams, to articulate, organize, and clarify their understanding of complex environmental or other systems. The user enters judgments about details which characterize the phenomenon; the computer handles logistics as well as logical analysis of the structure that the data manifest. Usually the data are solicited in the form of yes/no replies to questions typed in ordinary English.

The users prepare for an ISM exercise by choosing their problem's focal area, identifying its elements, and selecting any appropriate "transitive" relationships. One might define the elements to be, for example, EQ resources, the problems and opportunities identified during planning, planning objectives, or impacts of alternatives. With the above element sets, one might choose transitive relations which would cause the computer to ask questions of the form:

a. Does problem X aggravate problem Y?

b. Is objective X more important than objective Y?

c. Does fulfillment of objective X contribute to the fulfillment of objective Y?

d. Is resource X more important than resource Y?

e. Does impact X intensify impact Y?

The user is freed of having to laboriously consider whether the relation applies to all possible element pairs because, whenever appropriate, the computer automatically infers some "answers" by transitive inference given the responses that had already been entered. In addition to minimizing the users' unnecessary expenditure of time and systematically leading them through the problem, the ISM program also structures their inputs in a hierarchical graph or visual model which highlights the underlying system structure.

Although the ISM computer program incorporates aspects of graph theory, matrix algebra, mathematical logic, and set theory, users need not understand these subjects and can focus, instead, on making accurate judgments about structural aspects of the system being studied.

After loading the computer with a set of system elements and a contextual relation, the usual iterative process is to:

a. Reply to each of the computer's queries about whether the transitive relation applies to particular pairs of elements.

b. Closely examine the resulting hierarchical system model while identifying unanticipated results.

c. Update the model by incorporating new realizations or by correcting any erroneous inputs.

d. Study the new system model and iterate until satisfied with the results.

In addition to clarifying users' knowledge, the conduct of ISM always results in a visually displayed product--a "structural" model--which facilitates communication of a group's collective mental model by employing natural language and a visual diagram.

ISM potentially equips one to formulate a wide range of complex and formerly ill-articulated mental models which are held by users.

The ISM program's insistence on yes/no responses, which may seem unrealistic, also stimulates thought. Most leaders of ISM exercises have been able to reach consensus on each answer. But to do so, all issues and disagreements concerning language and substance may have to be explored in detail. Users devote enough effort to the explaining and clarifying of their reasoning, refining descriptions of the elements, and sharpening the transitive relations that their thought could not help but become more clear and precise.

There are alternatives to computerized ISM when the number of elements is less than about thirty.

ISM is a tool for qualitatively structuring elements in a system/problem; it does not directly result in quantification. Generally a computer program and access to a time-sharing system are needed to hold an ISM session (see the Carss Profile for specification of a manual procedure for ISM).

3. Applicability:

The planning of even small-scale civil works projects results in problems of assimilating, relating, and comparing numerous related elements. The elements may be planning objectives, problems and opportunities, or environmental resources. ISM provides a method for clarifying relationships when the data sets are large.

4. Advantages and Disadvantages:

ISM is best applied to systems/problems about which people have unclear, incomplete, or vague understanding. By breaking up the problem/system into components or a larger number of less difficult questions, ISM prevents users from having to immediately confront the whole of something that is ill-understood. The hierarchical graph that results from the users' responses serves as a tentative model for summarizing their knowledge which is visible and therefore readily corrected or refined. ISM results in awareness of both shared and conflicting understandings within the group. Also, conducting an ISM exercise helps integrate interdisciplinary teams and other groups, in part because participants tend to feel an "ownership" of the resulting model. ISM can be used when available data are weak or based solely on experience and judgment.

5. Previous Uses:

ISM has been fairly widely used by local, State, and Federal Governments as well as by private organizations. As Brand (1977) reports for the State of Louisiana, ISM has been applied for ranking and structuring regional goals in six of the eight areawide planning districts, for ranking and structuring transportation goals at the Rapides Area Planning Commission, and more recently for ranking constraints to development in suitability modeling for the Coastal Zone Management Program. ISM has also been used as an aid to citizen involvement in some of these projects and for demonstrations to professional groups.

6. Source/Contact:

Dr. John Warfield, Dept. of Electrical Engineering, University of Virginia, Charlottesville, Va. 22901

For ISM software, contact Bro. Raymond Fitz, President, University of Dayton, Dayton, Ohio 45469.

For information about use of ISM in Louisiana, contact the Department of Urban and Community Affairs, Office of Planning and Technical Assistance, 300 Louisiana Ave., Baton Rouge, La. 70804, telephone 504-389-5664.

Brand, DeWitt H. 1977. "Interpretive Structural Modeling in Louisiana: A Report on Its Application and Expanding Use in the State, " Planning Techniques Series, Issue Paper No. 1, Department of Urban and Community Affairs, Louisiana State University, Baton Rouge, La.

Fitz, Raymond. 1974. "Reflections of Interpretive Structural Modeling as Technology of Social Learning," in Proceedings, IEEE Conference on Decision and Control, 20-22 Nov., 1974, Phoenix, Ariz., Institute of Electrical and Electronics Engineering.

Malone, D. W. 1975. "An Introduction to the Application of Interpretive Structural Modeling," in Portraits of Complexity: Applications of Systems Methodologies to Societal Problems, M. M. Baldwin, Ed. Battelle Memorial Institute, Columbus, Ohio.

Warfield, John N. 1973. "An Assault on Complexity," Battelle Monogram No. 3, Battelle Memorial Institute, Columbus, Ohio.

1. Name:

Leopold, Luna B. et al. 1971. "A Procedure for Evaluating Environmental Impact," Circular 645, U. S. Geological Survey, Washington, D.C.

2. Description:

This matrix procedure for evaluating environmental impacts was one of the first assessment methodologies developed and was among the first matrix approaches to environmental impact assessment. The Leopold matrix is an open-cell matrix which displays 100 project actions across the horizontal axis and 88 environmental resources, conditions, or factors along the vertical axis. The cells, which are the intersections of the project actions and the environmental characteristics, are used to denote the potential impact and to evaluate impacts. Potential impacts are noted in terms of magnitude of impact, and weight, i.e., the importance of the impact. As presented by Leopold, evaluations of impacts are made subjectively on a 1-10 scale and recorded in the cells. After the intial evaluations are made, a reduced matrix may then be used to examine impacts of great magnitude or great importance.

3. Applicability:

The 88 × 100 matrix developed by Leopold was intended to be applied to various types of projects, and therefore does not emphasize water resource project actions or the resources affected by such projects. The 100 project actions and 88 environmental characteristics are to be viewed as a starting point, i.e., checklists to be modified on the basis of the alternatives under consideration. Modification of the Leopold matrix based on the resources and alternatives identified in the Inventory and Forecast and Formulation of Alternative Plans steps can be the initial step in the Evaluation of Effects. The potential impacts thus identified can serve to focus discussion during subsequent activities in assessment and appraisal. The subjective (1-10) rating system advocated by Leopold to evaluate impacts may be appropriate in the early stages of planning.

Initial application of the matrix can yield primary or first-order impacts. Higher order impacts may be determined by developing a matrix considering resource impacts on other resources (environmental resources on both the vertical and horizontal axes) as in the Sorenson profile.

4. Advantages and Disadvantages:

An advantage of the Leopold matrix is that it forces the assessment team to consider all possible interactions among project actions and resources. The criticism that matrix techniques can mask interrelationships and secondary impacts can be overcome by utilizing subsequent matrices as in Sorenson.

5. Previous Uses:

Users of the Leopold matrix indicate that it serves as a useful tool to identify impacts, organize and focus a study. When presenting the maxtrix results to the public, as in a public meeting, it has been found that some groups have difficulty in understanding the ratings of impact magnitude and importance.

6. Source/Contact:

See also: Schlesinger, B. and Douglas Daetz. 1973. "A Conceptual Framework for Applying Environmental Assessment Matrix Techniques," Journal of Environmental Sciences, pp 11-16.

Sorenson, Jens. 1971. A Framework for Identification and Control of Resource Degradation and Conflict in the Multiple Use of the Coastal Zone, M. S. Dissertation, Department of Landscape Architecture, University of California-Berkeley, Berkeley, Calif.

1. Name:

Linstone, Harold A. 1978. The Use of Structural Modeling for Technology Assessment, Portland State University, Portland, Oreg. (Prepared for the National Science Foundation/RANN by Portland State University.)

2. Description:

A structural model (SM) is a model which represents a system as a set of elements with pairwise relations linking some or all of the elements. It is graphically represented by points (or nodes) and connecting lines (or arcs). Structural modeling offers a geometric, semi-qualitative means to organize a technology assessment, develop a rough overview of it, and analyze various component problems. The primary value is the insight gained in the process of doing structural modeling, and the resulting model. Hence do-it-yourself efforts are nearly always preferable to buying packaged studies performed by outsiders. For similar reasons paper and pencil modeling should be attempted before turning to the computer.

Although this report is focused on technology assessment, environmental impact assessment resembles it in many ways. Therefore, this report is exceptionally germane to environmental analysis.

There are many SM tools--the authors identified about 100 techniques and briefly describe thirty-nine in a glossary. The basic building blocks, with a few notable exceptions, are trees and hierarchies, directed graphs and networks, or matrices. These tools are inherently reductionist in nature: the "system" is defined as a set of elements with interactions among them. There is no rigorous way of determining the appropriate set of elements, hence SM cannot provide a foolproof means of identifying the impacts of an alternative. The tools are simple and inexpensive to apply. They are complementary rather than duplicative; thus the user can apply multiple tools to the same problem and obtain different insights from each one.

However, simplicity exacts a price: assumptions and constraints. For example, relationships in SM are nearly always assumed to be pairwise, often transitive and/or linear.

Another price of simplicity is ease of misuse. The temptations -- to take any quantitative output as meaningful numbers, to assume comprehensiveness of a model, to ignore aspects which cannot be analyzed by the model--are not easy to avoid. But the tools can be very useful if applied properly.

In this project seven computer-oriented tools were tested in considerable detail: ISM, ELECTRE, SPIN, KSIM, IMPACT, and XIMP. Three other important approaches which may or may not be included formally in

SM were also studied: tools to aid in generating elements, a misfit variable concept (SOPA), and cross-impact analysis.

The criteria invoked by the author in order to identify structural modeling methods most promising for technology assessment were:

a. The application of the method must be possible in a matter of days.

b. The method must be easily understood and used by persons skilled in mathematics and modeling. Other persons or groups must be able to easily understand and use the method under the guidance of skilled facilitators and technicians.

c. The method must be very general in its range of applicability. For example, a computer algorithm used strictly to manipulate graph structures so that they will be easier to store within a computer is too specific.

d. The method must be fully implemented and tested in at least one case relevant to technology assessment or impact assessment. A proposed conceptual model is difficult to evaluate.

e. The method must permit use of subjective data.

Practical recommendations made by the authors include:

a. Do not use the computer unless paper and pencil prove unmanageable.

b. Do-it-yourself structural modeling (with expert support) is nearly always preferable to buying packaged studies by outside organizations.

c. Do not take for granted the built-in assumptions that accompany use of any particular structural modeling tool.

d. Network representations are at least as important as matrixes because networks better reveal indirect connections.

e. Of the seven tools examined most thoroughly, ISM and SPIN are easy to use and most useful in dealing with a large number of elements. KSIM is most useful when there is a small number of elements; it is relatively easy to use.

3. Applicability:

The structural modeling techniques analyzed and described by Linstone et al. are varied in what they were developed to accomplish. As a group, they provide assistance in developing models, defining relationships, and forecasting changes. These capabilities would be most useful for the assessment and appraisal in the Evaluation of Effects step and in Specification of Problems and Opportunities.

4. Advantages and Disadvantages:

The two volumes prepared by Linstone et al. reflect a major team research effort and can serve as an excellent reference to numerous structural modeling efforts. The several tools upon which they focused maximal effort have all been implemented and tested on the same applications ("pluralistic modeling"), therefore giving them a sound basis for making comparative evaluations of the techniques' advantages and disadvantages.

5. Previous Uses:

Sections for particular tools describe a variety of applications. To comparatively evaluate several of the more promising tools, the authors used each tool to construct alternate models of a mass transportation system.

Applications are various. Potential users should consult the authors' appendix devoted to the technique of interest to them.

6. Source/Contact:

Warfield, John M. 1976. Societal Systems: Planning, Policy and Complexity, John Wiley, New York, N. Y.

1. Name:

Mades, Dean M. and Tauxe, George. 1980. "Models and Methodologies in Multi-Objective Water Resources Planning," WRC Research Report No. 150, Water Resources Center, University of Illinois, Urbana, Ill.

2. Description:

This report reviews mathematical models which have applications in water resources planning. The report focuses on multiobjective evaluation models. The report reviews models which utilize linear programming, integer programming, nonlinear programming, and geometric programming. The strengths and weaknesses of each modeling approach are explained and specific applications of each approach are summarized.

During the course of the review of models, the authors developed a model using dynamic programming. This model is similar to the model used for surrogate worth trade-off (SWT) models (see Haimes profile) except that dynamic programming was utilized rather than linear programming. The model, called multiobjective dynamic programming (MODP), is an optimization model which identifies optimal solutions to an optimization algorithm.

As with SWT models, the model is defined in terms of objective functions and decision variables. The decision variables are measurable parameters which are to be optimized. The objective functions describe the project objectives on which an alternative is appraised. The objective functions are represented as mathematical expressions of the decision variables. For instance, the objective of minimizing the capital cost of a project may be expressed mathematically as a function of the total man-hours devoted to construction of the project (decision variable) and the mean radius of the impoundment (decision variable). In contrast, the objective of minimizing water loss due to evaporation is expressed as a function of only one decision variable, the mean radius of the impoundment.

Optimization occurs by considering one objective as the primary objective and the other objectives as constraining objectives. The objectives are in succession considered as the primary objective. The successive iterations provide a number of solutions or outcomes for the optimization. Iterations assist in identifying noninferior solutions to the evaluation. A noninferior solution has the property that no one objective can be improved without simultaneously degrading at least one other objective's level.

The use of dynamic programming in MODP allows consideration of the changes in the objective functions over a series of stages. The constraining objectives define state variables, the level of attainment of the variable changing from stage to stage (or with time). The level of attainment or value of each objective function in each stage is dependent on the level in the preceding stage. This allows MODP to be used sequentially or stepwise over a number of stages or, for example, through a number of river reaches.

The MODP model is expressed as the following algorithm:

$$F_1^j \; (F_2^j \; . \; . \; ., \; F_p^j \; , \; G_1^j \; , \; . \; . \; . \; . \; , \; G_m^j)$$

$$= \min \quad r_1^j \; (X_j)* \; F_1^{j-1} \quad (F_2^{j-2}, \; . \; . \; . \; F_p^{j-1} \; , \; G_1^{j-1}, \; . \; . \; . \; . \; , \; G_m^{j-1})$$

subject to

$$0 \leq F_k^j \leq \varepsilon \; K \qquad \text{for } K = 2, 3 \; . \; . \; . \; p$$

$$0 \leq G_i^j \leq G_i \qquad \text{for } i = 1, 2 \; . \; . \; . \; m$$

$$F_k^{j-1} = h_k^j \quad (F_k^j \; X_j) \qquad \text{for } K = 1, 2 \; . \; . \; . \; p$$

$$G_i^{j-1} = H_i^j \; (G_i^j \; , \; X_j) \quad \text{for } i = 1, 2 \; . \; . \; . \; m$$

where p = the number of objective functions
m = the constraining functions
j = time period or stage

F_k^j = level of attainment or value for the primary objective under constraint of ε_k , the level of constraining variable.

F_k^j for k = 2, 3 . . . p and G_i^j for i = 1,2 . . . m are state variables representing the "state" the system is in at state j. The secondary objectives are treated as state transformation functions, h_k^j . The level of attainment of each objective in stage j is represented by the state variable F_k^j . X_j is the level of the decision variable X at time j.

The * in the equation is used as a composition operator whose interpretation is multiplication or addition. The composition operator combines the short range addition to the level of the primary objective, r_1^j , with its level of attainment accumulated from stages X_1 through X_{j-1}. The transformation functions represented by h_k^j and H_i^j describe the transformations of the system's state in stage j, that is, the change in state of the variables F_k^j and G_i^j from the previous stage. These functions may be discontinuous or nonconvex.

The optimization is performed by solving the above system of equations for the different decision variables. The solutions to the optimization problem define levels of the functional objectives which minimize the value of the decision variables. These are the values of the objective functions which provide optimal solutions because the decision variables are minimized. At these levels, the improvement of one objective cannot be attained without the degradation of another objective.

Trade-off values between the functional objectives are calculated. The trade-off values allow comparisons to be made between objectives so as to clarify what is lost or gained by changes in levels of the objectives.

The output from a MODP model provides trade-off values for the functional objectives and the levels of the objectives that minimize the decision variables. These two pieces of information may be utilized in evaluating alternatives. Examination of the output facilitates identification of sensitive objective levels, i.e., levels where trade-offs become constant or insignificant. Knowing the optimal levels for minimizing the decision variables allows appraisal of alternatives on the basis of approaching the optimal level.

3. Applicability:

The MODP model can provide valuable input to the evaluation of alternatives. Planning objectives may readily be defined in terms of decision variables and objective functions. The trade-off values and optimal levels of the objective functions may be used in the Evaluation of Effects step for the appraisal of noncommensurable effects.

4. Advantages and Disadvantages:

Advantages of utilizing the MODP model are that it is capable of determining trade-off values and optimal levels for highly complex, dynamic systems involving noncommensurable objectives. The MODP provides a way to model dynamic systems in the evaluation of noncommensurable objectives. Due to complexity of the optimization algorithm, computer capabilities are required for computation, this perhaps being a disadvantage.

5. Previous Uses:

Although no field uses are documented, three hypothetical case studies are included.

6. Source/Contact:

Dr. Dean M. Mades, Department of Civil Engineering, University of Illinois.

1. Name:

McHarg, Ian L. 1969. Design With Nature, Natural History Press, Garden City, N.Y.

2. Description:

The McHarg approach employs transparencies of environmental characteristics overlaid on a regional base map. Overlay maps fall into two categories: physical impacts and social value impacts. Physical impact overlays map slope, surface drainage, bedrock foundation, soil foundation, drainage, erosion, and the like. Social value impact overlays show land values, tidal inundation, scenic values, wildlife, residential uses, historic values, water resources, forests, recreational areas, and the concerns of other administratively involved agencies, institutions, or the public. The basic value of this approach is that it provides a relatively simple means of determining how far-flung the impacts of a proposed alternative will be.

3. Applicability:

Overlay maps such as those suggested by McHarg can be very helpful in setting most appropriate study area boundaries to define the study area. In the process, an inventory of baseline conditions can be compiled to describe base conditions. Additionally, in comparing alternatives, it is crucial to maintain a consistent set of boundaries. This approach could be useful early in large, complex studies where it is difficult to trace the implications of potential alternatives.

4. Advantages and Disadvantages:

The cost associated with the preparation of overlay maps is more a matter of time than money. If baseline conditions in the general region within which a proposed project will take place have been well documented in the past, the preparation of overlay maps will be easy. If baseline information is not readily available, a great deal of legwork and field observation will be necessary.

Overlay maps help public agencies "visualize" the realms of impact and thereby set appropriate study area boundaries. Such maps also help one get an integrated overview of spatial patterns of environmental characteristics. The McHarg approach has the disadvantage of implicitly weighting all environmental characteristics equally.

5. Previous Uses:

6. Source/Contact:

Ian L. McHarg, Professor of Landscape Architecture and Regional Planning, Graduate School of Fine Arts, University of Pennsylvania, Philadelphia, Pa. 19104.

1. Name:

Mitchell, Arnold et al. 1975. "Handbook of Forecasting Techniques," IWR Contract Report 75-7, U. S. Army Engineer Institute for Water Resources, Fort Belvoir, Va. (Prepared for IWR by Center for Study of Social Policy, Stanford Research University, Menlo Park, Calif.)

2. Description:

This report is the result of a review of 150 techniques which have been used for forecasting environmental, technological, economic, and social conditions. The review identified 12 basic forecasting methods which are suitable for a wide range of forecasting needs. The basic forecasting techniques are:

a. Trend Extrapolation. Trend extrapolation is the general name for a variety of mathematical forecasting methods all of which determine future values for a single variable through some process of identifying a relationship valid for the past values of the variables and a solution for future values. Although the technique is generally useful for only a single variable, this variable may be highly complex in that it may reflect numerous trends.

b. Pattern Identification. Forecasting methods based on pattern identification seek to recognize a development pattern in historical data and to use this often obscure pattern as the basis of forecasting future events. The method is useful both for time-series data, where more direct extrapolating methods do not work, and for interpreting numerous social trends.

c. Probabilistic Forecasting. Many phenomena for which forecasts are needed appear to change randomly within limits. Probabilistic forecasting methods use mathematical models of such phenomena. Numerical odds are assigned to every possible outcome or combination of outcomes. On the basis of such assigned odds, predictive statements are made about the future behavior of the phenomenon studied.

d. Dynamic Models. Dynamic models of complex, nonlinear systems are extremely useful for forecasting futures resulting from interacting events. The simulation model, which is usually numeric, reveals the evolution of systems through time under specified conditions of feedback. By changing equations or adding interacting trends, a large number of possible futures can be explored in computer runs. Dynamic models are also helpful in gaining qualitative insight into the interactions of system elements.

e. Cross-Impact Analysis. Cross-impact analysis strives to identify interactions among events or developments by specifying how one event will influence the likelihood, timing, and mode of impact of another event in a different but associated field. Cross-impact analysis is used not only to probe primary and secondary effects of a specified event, but to improve forecasts and to generate single forecasts (or scenarios) from multiple forecasts. Cross-impact analysis is a basic forecasting tool helpful, if not essential, in more sophisticated forecasting.

f. KSIM. KSIM is a cross-impact simulation technique used to better forecast and assess long-range requirements and impacts of water resource development alternatives. The technique provides a tool to interface broad planning issues with detailed dynamic models so that more effective use can be made of planning resources. Both qualitative and quantitative data can be used--a unique characteristic. KSIM combines a small group workshop procedure with a mathematical forecasting model and a computer program to generate changes over time in a few significant planning variables. The method helps to identify planning needs, develop models, and test the consequences of policy actions. The technique requires expert leadership and access to a computer. A KSIM computer program is available.

g. Input-Output Analysis. Input-output (I-O) analysis is a means of interrelating industry inputs and outputs in a single model, showing the consequences to all other sectors of a specified change in one. Different models deal with the Nation, with regions, with specific industries, and so on. I-O analyses are of great value in quantifying changes in a region's or subregion's commodity flows and likely industrialization patterns resulting from specific projects--such as improved navigational facilities or a new recreational site.

h. Policy Capture. "Policy capture" involves building a model that, given the same information the individual has, will accurately reproduce his judgments and hence his "policies." The goal is not simply to predict or reproduce judgments accurately; rather policy capture seeks to generate descriptions of the judgmental behavior that are helpful in identifying characteristic differences between individuals. It is felt that the judgmental process can be described mathematically with a reasonable amount of success.

i. Scenarios and Related Methods. Scenarios and related methods depend upon logical, plausible, and imaginative conjectures that are most properly regarded as descriptions of potential futures rather than as probabilistic forecasts of actual futures.

Such methods, like all other qualitative methods, are most often used in conjecturing about complex, little-understood phenomena for which more rigorous quantitative forecasting methods do not exist.

j. Expert-Opinion Methods. Expert-opinion methods include the use of panels, surveys of intentions and attitudes, and Delphi polls. It is emphasized that the definition of expertise as well as the limits of its use for forecasting purposes can be considered in terms of three aspects: topic, sponsor, and other eventual users of the study's end-product. Expert-opinion methods may be used either for actual forecasts or to make conjectural explorations of potential futures.

k. Alternative Futures. Alternative futures methods of forecasting emphasize what may plausibly happen rather than what is predicted to happen. Study of an array of alternative futures is helpful in setting organizational long-term goals and policies, in charting primary strategies, and in developing contingency plans. It is pointed out that a given potential development may or may not occur; if it occurs, it may happen at any of many different times and may have any of many different potential impacts. Each unique combination of these and other variables constitutes a different alternative future. Morphological analysis and divergence mapping are discussed as examples of alternative futures methods. The techniques are best adapted to mid- and long-term planning.

l. Values Forecasting. Of all the techniques for looking ahead, values forecasting perhaps holds the greatest promise while to date it has yielded the fewest practical results. People's values (priorities, opinions, attitudes, and so on) are of crucial importance in judging what agency actions and policies they will support. Data on these matters can be collected through survey methods. Forecasts of changing values usually involve clustering values into a typology and forecasting on the basis of demographic shifts or broad societal scenarios.

3. Applicability:

The forecasting techniques documented in this report may be used to forecast future conditions related to the problems and opportunities specified in planning.

4. Advantages and Disadvantages:

5. Previous Uses:

6. Source/Contact:

1. Name:

Mumpower, Jeryl and Bollacker, Lee. 1981. "User's Manual for the Evaluation and Sensitivity Analysis Program (ESAP)," Technical Report E-81-4, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss. (Prepared by the Center for Research on Judgment and Policy, Institute of Behavioral Science, University of Colorado, Boulder, Colo.)

2. Description:

The ESAP is an environmental evaluation tool developed to assist CE planners in evaluation of water resources alternatives. The ESAP evaluation of alternatives is based on the impact on the resources affected by the alternatives. The ESAP program has been placed on Boeing Computer Services so as to be available to all Corps Districts.

For evaluation of alternatives, ESAP combines information about the impacts on resources affected by the alternatives with value information about the importance and preferred levels of the resources. Because there is always some degree of uncertainty in impact predictions, ESAP allows the user to input a measure of uncertainty for the impact projections. This allows the user to determine how the evaluation could vary given the level of uncertainty to impact predictions. Various groups and individuals have different perceptions about the importance of the resources affected by a proposed project. In addition, these groups may disagree on the preferred or most desirable level of a resource. These value differences result in differing evaluations on the desirability of alternatives by the various groups. ESAP allows each group or individual to input its own judgments, i.e., weights and information about preferred resource levels, such as, the more, the better; the less, the better; or a midrange level is optimum.

After inputting data on the resources affected by alternatives, information about the importance and preferred levels of resources, and uncertainty information, ESAP can evaluate the alternatives for each group, and determine the sensitivity of the evaluations to uncertainty and differences in value judgments.

The evaluation problem or environmental quality evaluation is approached by assembling all the resources affected by the alternatives into an evaluation framework. The overall evaluation framework used by ESAP is that of a resource hierarchy. The resouce hierarchy organizes and specifies the dimensions of the evaluation problem. The environmental variables or resources affected by the alternatives should appear some place in the hierarchy, or TREE as it is called in ESAP. The overall evaluation dimension, that is, the environmental evaluation problem, is known as the root of the TREE. The resources affected by an alternative are arranged in levels of increasing specificity moving away from the root.

The first level of resources emanating from the root usually contains general resources categories such as terrestrial resources. The general categories are subdivided into more specific resources. A resource category is subdivided to the extent necessary to exhaust the meaning of the category, that is, adding additional subcategories would not add to the meaning of the analysis. Usually, from two to four levels or subdivisions are needed to exhaust the meaning of the general categories. The final subdivisions of the categories are usually specific measurable indicators, such as pH, acres of habitat, or numbers of archaeological sites. Whatever the resource, the final subdivision must be measurable. These final subdivisions are known as leaf variables and intermediate variables are known as branches.

The development of the TREE is the most important step in ESAP analysis because all other procedures are based on the TREE structure. Development of the TREE forces planners to analyze the relationship of the resources and how the evaluation problem is conceived.

After the TREE is defined, data on the resources are entered. Because the variables of each subdivision in the TREE exhaust the meaning of the next higher level, only data for the leaf variables need be entered. The user enters data for:

a. The range of data values possible for each leaf variable.

b. Impact predictions for leaf variables for the alternatives being evaluated.

c. Information describing the uncertainty (uncertainty evaluation is optional).

The formation of the TREE and inputting the data on impact predictions and uncertainty set up the ESAP analysis. These data are used by each group for evaluation of alternatives. As the planning study progresses, it may be necessary to alter the TREE, change impact predictions, or change uncertainty information. ESAP provides for ready updating of the analysis.

For a group to evaluate alternatives, the group's value judgments must be added to the analysis to complement the TREE and impact prediction data. Each group or individual is required to input two pieces of information for the evaluation. Each group provides information on the importance (weights) of each of the resources affected by the alternatives. The weights may be entered in a number of ways; the program normalizes the weights entered. The other value information required is the determination of preferred or desired levels of the resources. The preferred levels are input by describing a functional relationship for each of the resources. The functional relationship (called FORMS in ESAP) establishes a correlation between a given level of a resource and a measure of preference or quality. A 0-100 scale is used for the preference rating. The user inputs a maximum and minimum value for a variable and then indicates how the maximum, minimum, and intermediate values relate to the 0-100 scale. A total of nine standard relationships are available with ESAP. The most commonly used forms are:

a. Positive linear, i.e., the more of the resource, the better.

b. Negative linear, i.e., the less of the resource, the better.

c. Special, a midrange level of the resource is best.

ESAP evaluates alternative plans by considering the plan's impact on the leaf variables. A single evaluation score between 0 and 100 is produced for each alternative. The evaluation score is produced by summing variable scores for each of the leaf variables. The variable scores are determined as follows: The impact projections for the leaf variables are used to determine the rating or preference level (the term "rating" is used by ESAP). The variable's rating is then multiplied by the weight assigned to that variable. The variable score represents a weighted preference for the projected impact. ESAP sums the variable scores to produce an overall evaluation score.

ESAP utilizes two evaluation procedures, EVALUATE and COMPARE. EVALUATE is used to evaluate alternatives for each group for which weights and functional relationships have been specified. After the alternatives have been evaluated by each group, COMPARE is used to determine where the differences between groups lie in the evaluation.

There are several options within the EVALUATE routine. The various options produce overall evaluation scores, variable scores and variable ratings for each alternative evaluated. These options allow the user to explain a group's preferences for the different alternatives in terms of the weights and ratings assigned to the impacts by the group. By examining the variable score for an alternative, the user can determine the contribution of each variable to the alternative's overall score. The user can compare the evaluation of one alternative with the evaluation of another alternative to determine which variables are responsible for differences in the overall evaluations. Using uncertain data with the EVALUATE procedure demonstrates the sensitivity of the evaluation to uncertainty. The user is able to examine how the overall evaluation scores and variable scores may vary given a specified level of uncertainty.

Use of the EVALUATE procedure thus yields the following information for each group:

a. Overall ranking of alternatives by evaluation scores.

b. The resources responsible for the variation in evaluation scores.

c. Contribution of each variable to the overall evaluation.

d. Sensitivity of the evaluation to uncertainty.

After all groups have evaluated the alternatives, the COMPARE procedure is used to determine the manner in which the evaluations concur or diverge. The available options display how the groups compare in their evaluation of all alternatives. COMPARE assists in determining if a concensus exists on the most desirable alternative. Output from COMPARE can display the range of variable scores across all groups, or the differences in scores of only two groups. This assists the planner in determining which resources are perceived to be most important to the evaluation by all groups. As with EVALUATE, uncertain data may be used to display the range of evaluation scores for all groups.

3. Applicability:

ESAP is a systematic, tractable method for evaluating alternatives based on the impacts on affected resources. The groups evaluating the alternatives never make preferences for specific structural features, such as a large mainstem reservoir rather than smaller tributary reservoirs. If the results of the ESAP evaluation are inconsistent with the perceived ranking of alternatives, it may be an indication that the group is making judgments based on incorrect perceptions of the given alternatives rather than on factual knowledge of impacts. Incongruous evaluations may indicate that the ESAP analysis needs further development, i.e., the evaluation framework (the TREE) may require changes or the user may wish to alter the weights and functional relationships.

The ESAP analysis is not intended to determine a single best alternative, but rather to lay out how groups evaluate the alternatives being considered. The displays from ESAP are designed to show where the differences in evaluations lie.

By using ESAP early in the planning process, the planner can focus attention on those variables that make a significant difference in the choice of alternatives. Variables which are less critical may not require further analysis or more refined predictions. By understanding the impacts of uncertainty in projections, a planner can determine if more precise impact predictions would affect the choice of the most desirable alternatives.

ESAP is available on Boeing in both batch and interactive modes, batch being somewhat cheaper to use. ESAP is written as a "user-friendly" program, readily useable by those unfamiliar with computer programs. An ESAP analysis may be stored on Boeing and updated periodically as the study progresses.

4. Advantages and Disadvantages:

The advantages of using ESAP for environmental evaluation in water resource planning are that ESAP is systematic and tractable. The analysis is based totally on input from the user. The output displays available from COMPARE and EVALUATE options clearly show how the alternatives are evaluated and the reasons for the evaluations in terms of ratings, weights and uncertainty.

A chief disadvantage of ESAP is that it is data intensive. Impacts on leaf variables must either be measurable or readily converted to a scaled form. This limitation can be overcome if use of ESAP is anticipated before data are collected and the data collected in a form which may be used by ESAP.

5. Previous Uses:

ESAP was field tested on a medium size flood control project for the Los Angeles District. The ESAP study became part of the Stage II report and the members of the planning team felt that the ESAP analysis assisted in focusing their efforts as they prepared for Stage III.

6. Source/Contact:

Jim E. Henderson, FTS 542-3305 or (601) 634-3305, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Miss.

1. <u>Name</u>:

Ortolano, Leonard, Ed. 1973. "Analyzing the Environmental Impacts of Water Projects," IWR Report 73-3, Department of Civil Engineering, Stanford University, Stanford, Calif. (Prepared for U. S. Army Engineer Institute for Water Resources, Fort Belvoir, Va.) (NTIS AD-766 286/SWU)

2. <u>Description</u>:

This report summarizes a Stanford seminar on the environmental impacts of water resources projects. The seminar focused on NEPA, its judicial interpretations and agency implementation, and the environmental impacts associated with major CE projects. The seminar interpreted environment to mean the natural environment and did not address the social and economic impacts required by NEPA. The approach to impact assessment described in this report is considered an ad hoc approach to impact assessment.

The seminar developed an impact assessment framework which was then field tested. This framework places a great deal of emphasis, for impact identification and assessment, on the interdisciplinary composition of the impact assessment team. The assessment framework developed consists of the following five steps:

<u>Step 1</u> - Preliminary Identification of Impacts. This involves a review of the types of impacts typical of the project in question, in addition to considering existing conditions so as to be able to focus on the types of impacts that require more careful consideration.

<u>Step 2</u> - Broad-Brush Data Gathering and Impact Forecasting. The purpose of this step is to produce recommendations from the assessment team as to how the resources available for impact analysis ought to be spent, i.e., what resources and impacts are to be addressed in a detailed fashion. This step is accomplished by utilizing data from existing sources, project alternatives, and employing "back-of-the-envelope" type forecasts to predict environmental changes. Examination of these forecasts enables the assessment team to identify potential impacts and data-gathering needs, so as to formulate a plan of study for the assessment.

<u>Step 3</u> - Preliminary Integration and Resource Allocation. This step is intended to formally integrate the individual impressions of the assessment team to identify significant impacts. If this integration uncovers potentially important areas requiring further investigation, then the proposals resulting from Step 2 are revised. It is at this point that decisions are made as to how the time and efforts of the assessment team are to be allocated, e.g., which impacts require greater examination, which resources are to require more extensive data gathering, or the level of sophistication and detail appropriate for data gathering and impact forecasting.

Step 4 - Detailed Data Gathering and Impact Forecasting. The data gathering and impact forecasting studies, which were decided on in the previous step, are implemented.

Step 5 - Final Integration. After the various studies are completed, the results are brought together and summarized. The results from some studies may raise new issues or may not provide the information for which they were intended. This likelihood complicates the process of integration. A review of the impact assessment methodologies, techniques, and aids to environmental analysis which have been developed is provided. The environmental analysis tools reviewed could be utilized at this point.

In addressing the impacts associated with reservoir projects, a 1973 review of the literature is assembled. The effects of impoundment on the physical environment, on water quality parameters, and on the biological environment are explained for downstream reaches as well as for the reservoir.

Channelization impacts are considered less extensively in the form of a summary of the 1971 Congressional Hearings on the Effects of Channelization on the Environment.

A literature review of the chemical and biological impacts of dredging and disposal is included. The section on biological impacts addresses the impacts of dredge material disposal on primary production, species composition, fish and wildlife effects, and biological magnification of toxic materials. The section on chemical impacts addresses impacts due to the constituents of the spoil material. Impacts examined include changes in dissolved oxygen and changes caused by toxic materials and nutrients likely to be found in dredged material. The chemical and biological effects of dredge disposal are treated separately for offshore dredging, where disposal is likely to be subaqueous, and estuarine dredging, where subaerial disposal is likely.

3. Applicability:

The sections of this report on impacts associated with the various types of projects could serve to guide the Evaluation of Effects step. The assessment framework developed, utilizing increasingly detailed data gathering and integration of the work by planning team members, presents somewhat of an ideal situation. The impact assessment framework developed could be implemented but would require a high level of interaction among planning members. The logistics of attaining the level of teams' interactions required may be difficult to attain in many situations.

4. Advantages and Disadvantages:

The sections on impacts for the different type projects provide a basis for identifying potential impacts, though quantitative forecasting techniques are not included.

The impact assessment framework which was developed has the disadvantage of being dependent on a high level of interaction between team members.

5. Previous Uses:

The impact assessment framework was applied to a medium size flood control project in Carmel Valley, Calif. (SPN). This application followed the framework step-by-step. It was found that in Step 3, Preliminary Integration and Resource Allocation, there was disagreement as to the level of sophistication necessary for some of the forecasts.

6. Source/Contact:

The sections of this report dealing with impacts of different type projects provide an extensive bibliography for each type of project.

Dr. Leonard Ortolano, Dept. of Civil Engineering, Stanford University, Stanford, Calif. 94305

1. Name:

Reppert, Richard T. et al. 1979. "Wetland Values: Concepts and Methods for Wetlands Evaluation," IWR Research Report 79-R1, U. S. Army Engineer Institute for Water Resources, Fort Belvoir, Va.

2. Description:

This manual was prepared to assist in the evaluation of wetlands for Corps permit and civil works programs. Wetland characteristics used for evaluation are divided into two categories, primary functions and cultural values. The primary functions encompass the ecologic, hydrologic, and institutional characteristics of wetlands. Cultural values cover the socioeconomic and other socially perceived considerations.

Primary Functions are:

- a. Food Chain Production
- b. General and Specialized Habitat for Land and Aquatic Species
- c. Aquatic Study Areas, Sanctuaries and Refuges
- d. Hydrologic Support Function
- e. Shoreline Protection
- f. Storm and Flood Water Storage
- g. Natural Groundwater Recharge
- h. Water Purification

Cultural Values are:

- a. Commercial Fisheries
- b. Renewable Resources and Agriculture
- c. Recreation
- d. Aesthetics
- e. Other Special Values

For each of the primary functions, the manual sets out evaluative criteria to be used to determine numerical ratings for the functions. Evaluation of each of the primary functions is determined by rating the evaluative criteria for that function. For example, the function of Shoreline Protection is evaluated through use of the following evaluative criteria:

- a. Vegetation Characteristics
- b. Areal Extent
- c. Fetch (Wind)
- d. Cultural Development

For each criterion, the wetland in question is rated on a 1 to 3 scale (3=High, 1=Low) indicating how the wetland is valued on that criterion. For each criterion, a rationale for assigning the ratings is included. To the extent possible, the rationales developed are applicable to any wetland, but some criteria, e.g., the Food Chain Support criteria, require development of a value rationale based on ecological factors specific to the area or wetland system in question. A single value is produced for each of the primary functions. If a function has more than a single evaluation criteria, the criteria values are averaged to get a single value.

The cultural values of wetlands are discussed in terms of socio-economic benefits and culturally perceived values. Information useful in the evaluation of cultural aspects of wetlands is presented though not in the level of specificity as for the primary functions. The evaluation of the cultural values is largely left to the professional judgment of the field planner or permit personnel, thus no evaluation criteria or rating rationale are presented. Evaluation of wetlands based on primary functions and cultural values requires consideration of data normally assembled or available in the course of planning or readily determined in the field.

The manual suggests two evaluation frameworks for application of the primary functions and cultural values. The first framework, deductive analysis, is most appropriate for use where site alternatives are not presented, such as for permit purposes, or for describing base conditions in planning. The deductive analysis is based on a systematic evaluation of the degree to which the wetlands under examination satisfy each of the primary functions and cultural values. The second suggested evaluation framework, a comparative analysis approach, is a strictly quantified analysis of wetlands. The authors suggest the comparative analysis be used when considering alternative sites because the quantified ratings may be compared between sites.

3. Applicability:

The evaluation approach presented in this manual provides a systematic evaluation of wetlands. The rationales for primary functions and information on social values provide the basis for an evaluation checklist which may be used to evaluate any wetland affected by CE permit or civil works function. The rationales for assigning values to primary functions and evaluating social values may be subject to amendment based on professional judgment and specific applications.

A deductive analysis framework could be utilized in the Inventory and Forecast step to describe the quality of existing wetlands. A comparative analysis could be used to choose project sites to incur the least environmental damage.

4. Advantages and Disadvantages:

The advantages in use of this approach to wetlands evaluation are that it is a systematic, quantitative, yet relatively straightforward approach to evaluation of wetlands.

5. Previous Uses:

During development of this manual, the concepts and methods were tested in two ways. First, the technical concepts and evaluation methods were presented for review to Corps and EPA personnel with responsibility for wetlands. In addition, the methods were used by a contractor to evaluate a number of wetland areas. One of the evaluations is documented in the manual. It was the consensus of the review and the field tests that the concepts are technically sound and that use of the methods provides an objective evaluation of wetland values.

The methods have been utilized by EPA to analyze waste disposal alternatives in Pennsylvania. No Corps applications of the total procedures have been documented.

6. Source/Contact:

Richard Reppert, Board of Engineers for Rivers and Harbors, Kingman Bldg., Fort Belvoir, Va., FTS 325-7210.

See also: Hansen, William J. et al. 1979. "Wetland Values - Contributions to Environmental Quality or to National Economic Development?" in Estuarine Perspectives, Proceedings of the Fifth Biennial International Estuarine Conference, Jekyll Island, Georgia, 7-12 October 1979, Victor E. Kennedy, Ed. This article reviews the evaluation process set out in "Wetland Values" and compares it to two other evaluation approaches, the Wetland Evaluation System (Galloway, 1978) and Judgment Analysis Methods (Hammond and Adelman, 1976).

1. Name:

Ross, John H. 1974. "Quantitative Aids to Environmental Impact Assessment," Occasional Paper No. 3, Environment Canada, Lands Directorate, Ottawa, Canada.

2. Description:

Despite the word quantitative in the title, this paper presents a structural modeling approach to environmental impact assessment akin to ideas subsequently developed by Linstone (see Linstone Profile). The main contributions of the paper are to provide and apply a technique for tracing higher order impacts given an "environmental component interaction matrix." To use the technique, one forms a matrix with a column and row for each environmental component. A 0 or 1 is placed in each element of the matrix to show influence (absence or presence, respectively) of column components on row elements. However, influence of sockeye salmon on herring, for example, does not necessarily imply influence of herring on sockeye salmon. Although this matrix shows first-order direct relationships among components, it does not reveal indirect relationships; for example, if component C influences D which influences K which influences B, C indirectly influences B although that information is not immediately discernable from the interaction matrix. What the author provides is a simple mathematical technique ("raising the matrix to a power") that can be learned readily and applied rather mechanically to identifying N-th order interactions of the components. Simple programs are available for programmable hand calculators to do the same.

Ross provides two means for displaying the above results. First, one can summarize the interactions in a "minimum link matrix" showing the lengths of the chains of influence between the pairs of environmental components. For example, a 1 indicates a chain of length 1 (direct influence), a 2 indicates a chain of length 2 (second-order influence), and so forth. Second, one can display the interactions in a more visual network form showing which elements are linked with one, two, etc., links.

3. Applicability:

This technique is a structural modeling method developed to identify and trace higher order impacts. As such, it can provide an easily used approach to assist in the Assessment in the Evaluation of Effects step to ensure that all impacts and the interrelationships to other impacts are considered.

4. Advantages and Disadvantages:

This technique has the advantage of helping one systematically trace higher order impacts on environmental components, thereby increasing the likelihood that all significant impacts will be uncovered. It is also quick, easy, and economical to apply. It could easily be used to strengthen many impact assessment methodologies which require an impact matrix. This technique has several limitations which users should consider while applying it:

a. The results are qualitative rather than quantitative.

b. The interdependencies are treated as if they were of equal importance and of equal strength.

c. Interdependencies are rarely static.

d. No means are provided for aggregating impacts for each alternative.

5. Previous Uses:

This technique has been applied by a six-person interdisciplinary team directed to consider alternatives for a lumber transshipment facility and rank the alternatives in order of their environmental disruption (Lands Directorate 1974). Various alternatives required dredging, filling, and construction of lumber mills.

6. Source/Contact:

Lands Directorate, Environment Canada. 1974. "An Environmental Impact Assessment of Nanaimo Port Alternatives," Report prepared for the Canadian Ports and Harbors Planning Committee.

Other structural modeling approaches are presented in the Linstone et al. Profile.

1. Name:

Schlesinger, B. and Daetz, Douglas. 1973. "A Conceptual Framework for Applying Environmental Assessment Matrix Techniques," The Journal of Environmental Sciences, pp 11-16.

2. Description:

This article compares various matrix techniques utilized for impact assessment and evaluation. Matrix techniques are useful to present impact analysis results in a systematic and understandable manner and provide a basis for managing and delineating the tasks of a complicated impact assessment.

Matrix techniques are based on a system of two checklists, one for the major components, e.g., structural or construction-operation phases, of a proposed action, project, or facility, and the other checklist for relevant aspects of the environment. Individual impact assessments then are indicated as the effect of each project component upon each environmental resource.

The assessments which are displayed within the body of a matrix are in terms of ordinal scales such as 0 to 10 or 0 to 100. All of the numbers in a matrix are the result of judgmental processes which should be supported by factual information. The information about impacts which is displayed in a matrix may include identification, magnitude, importance, or duration of an impact; interrelationships among environmental elements; probability of the impact occurring and sensitivity analysis; and indication of possible mitigation problems. The matrix methodologies most often cited for water resource planning incorporate identification, magnitude, and importance into the display of impacts. The matrices used for water resource projects generally include detailed descriptions of the proposed project. The reviewed matrix techniques include:

a. Geological Survey - See Leopold Profile.

b. Battelle Environmental Evaluation System (EES) - See Dee Profile.

c. Coastal Zone Studies - See Sorenson Profile.

d. Bechtel Environmental Assessment Matrix - This system is designed to assess alternate ship building sites. The format of project aspects and environmental resources is similar to the Leopold matrix. A weighting system attaches importances to resources. A time-sharing computer program performs a sensitivity analysis by multiplying the environmental weights individually by factors such as zero, one-half, two, and ten (to represent impact magnitude) and recalculating the site priority each time. Identification, magnitude, importance, and sensitivity are thus addressed by this methodology.

e. Optimum Pathway Matrix - This methodology is similar to the Environmental Evaluation System, except that duration is treated explicitly. The importance indicator is split into separate short-term and long-term weights. The weights are systematically combined according to the arbitrary rule:

$$\text{long term} = 10 \times (\text{short term})$$

A sensitivity analysis is performed upon the final results to indicate confidence limits surrounding the cumulative impact ratings. The ranking of alternatives is expressed then in terms of upper and lower bounds (95 percent confidence limits). This methodology is designed for use in highway routing decisions, but could be adapted for water resource planning.

Attributes of the reviewed matrix techniques are compared in Table 1.

Table 1

MATRIX PARAMETER	SELECTED MATRIX APPROACHES				
	COASTAL ZONE STUDY	GEOLOGICAL SURVEY	BECHTEL MATRIX	BATTELLE SYSTEM	OPTIMUM PATHWAY MATRIX
Identification	●	●	●	●	●
Magnitude		●	●	●	●
Importance		●	●	●	●
Duration					●
Interrelationships	●				
Probability					
Sensitivity			●		●
Mitigation	●				
OTHER PROPERTIES:					
Economic Considerations					●
Details of Proposed Project	●	●	●		

3. Applicability:

Matrix techniques are useful for the Inventory and Forecast and Evaluation of Effects steps. In Inventory and Forecast, the matrix can serve as a guide to data collection activities and later as a checklist for completeness of field data. The matrix display identifies sources of potential impacts and may be used to indicate impacts on significant or critical resources.

The information displayed in a matrix provides a basis to guide evaluation. Matrix evaluations of alternatives provide information to be utilized in a trade-off analysis. The techniques, which include sensitivity analysis, provide an evaluation of uncertainty.

4. Advantages and Disadvantages:

The major advantage in a matrix approach to impact assessment and evaluation is that it is a systematic method for the evaluation of impacts.

Disadvantages of matrix techniques are that the matrix may neglect secondary or indirect impacts, and the use of ordinal scaling may tend to misrepresent the magnitude or importance of impacts. Care must be used to ensure that the checklist used does not omit important project features or environmental resources.

5. Previous Uses:

6. Source/Contact:

Schlesinger, B. and Hughes, R. A. 1972. "Environmental Assessment of Alternate Shipbuilding Sites," Bechtel Corporation, San Francisco, Calif.

Institute of Ecology, University of Georgia. 1971. "Optimum Pathway Matrix Analysis Approach to the Environmental Decision Making Process," 1971. Athens, Ga.

1. Name:

Sellers, Jackie and North, Ronald M. 1979. "A Viable Methodology to Implement the Principles and Standards," Water Resources Bulletin, Vol 15, No. 1, pp 167-181.

2. Description:

This article describes the use of goal programming to evaluate alternatives. Goal programming is a linear modeling technique used to evaluate an alternative on multiple objectives, thus its utility for evaluation under Principles and Standards (P&S). Goal programming does not seek to maximize the NED or EQ objectives, but instead to satisfy the multiple objectives set out as planning objectives. Alternatives are evaluated on the basis of how they meet or exceed the desired levels set out in the objectives. Goal programming is based on determining which of the alternatives most nearly approximate the desired or goal levels for the resources considered in the planning objectives. This is accomplished by determining deviations from the desired levels. The so-called "highest and best use" alternative is the one which minimizes the deviations from the desired levels. Thus, goal programming seeks to minimize the deviations from desired levels of resources, rather than maximizing any one objective. Nonattainment of goals is penalized by weighting the deviations. In some cases overachievement is penalized, while other goals are penalized for underachievement or for any deviation from goal levels.

To use goal programming to evaluate an alternative's fulfillment of objectives,

a. A desired level or goal is set for the attainment of a planning objective. This desired level may be preservation of X number of acres of wildlife habitat; improvement of water quality to ensure Y ppm dissolved oxygen; or provide flood protection to Z acres of agricultural lands. Economic objectives use dollars for units while environmental units vary with the resource.

b. For each of the resources considered in the planning objectives, a range of probable attainable levels is developed. This range represents the range of levels likely to be obtained by the alternatives.

c. For each resource considered in the planning objectives, weights are determined for deviations from the goal levels. Using the predicted ranges of resource levels, a penalty per unit deviation is calculated for each resource goal.

d. Using impact projections, deviations from goal levels are weighted. The weighted deviations are then summed for each alternative.

Examination of the summed weighted deviations shows how well the alternatives meet the planning objectives. Alternatives which minimize the deviations come closest to meeting the goal levels for the planning objectives.

3. Applicability:

The data requirements and level of specificity for goal programming make it applicable to evaluation of planning objectives where specified levels of goals or resources are set (for addressing problems and opportunities) and plans are formulated to achieve the goals. Goal programming may be used to evaluate studies with a large number of planning objectives and/or numerous alternatives. Large data sets may be managed more easily with computer assistance. Goal programming enables the planner to evaluate alternatives based on the mix of benefits, i.e., impacts on a number of planning objectives.

Information pertaining to the desired or goal levels of resources and impact projections is available in planning reports and other working documents, thus no additional data need be collected. The desired levels and penalty weights may be changed using sensitivity analysis to determine how the evaluation could be affected by changes in those values.

The results of goal programming may be utilized to determine a ranking of alternatives or to determine which alternatives achieve a satisfactory level of goal achievement to be carried to a later stage of planning.

4. Advantages and Disadvantages:

Goal programming provides a systematic, tractable method to evaluate alternatives under multiobjective planning. The analysis provided by goal programming is only as good as the data it is based on. The desired goal levels and penalty weights rely on value judgments. (Sensitivity analysis can be used to determine if varying the values would change the overall rankings.)

A chief criticism of goal programming is its basis in linear programming. Because a number of environmental parameters exhibit nonlinear behavior, goal programming is criticized as being inappropriate for use in their evaluation.

5. Previous Uses:

Goal Programming was utilized to evaluate development alternatives in the Cross Florida Barge Canal Restudy of the Jacksonville District. It was found that the required quantified data for goals (planning objectives) and impact predictions were not always available. In addition, Jacksonville District personnel criticized the methodology (linearity assumptions).

Goal programming has been used by the Forest Service in land use planning in the western states. The Forest Service has developed a computer program, GPLUS, to be used in goal programming applications. (see Russell under Source/Contact).

6. Source/Contact:

John Burns, FTS 242-6240, of the South Atlantic Division, formerly of the Jacksonville District, was the District contact for the contractor doing the goal programming application. The Cross Florida Barge Canal Restudy goal programming application is documented in:

North, Ronald M. 1976. "The Highest and Best Uses of the Oklawaha River Basin and Lake Rousseau for the Economy and the Environment," Inst. of Natural Resources, University of Georgia, Athens, Ga.

Dr. Ronald North, Inst. of Natural Resources, University of Georgia, Athens, Ga., (404) 542-1555.

Neely, Walter P. et al. 1976. "Planning and Selecting Multiobjective Projects by Goal Programming," Water Resources Bulletin, Vol 12, No. 1, pp 19-25.

Russell, Robert, Thor, Edward C. and Elsner, Gary H. 1979. "GPLUS., A New Program for Multiple Objective Planning," in 27 Feb-1 Mar 1979 Proceedings of the Multiple Objectives Planning Workshop, Miscellaneous Paper No. 7, College of Agriculture, University of Arizona, Tuscon, Ariz. GPLUS is being developed by the Pacific Southwest Forest and Range Experiment Station (415) 486-3382.

1. Name:

Soil Conservation Service, "Guide for Environmental Assessment," Federal Register, Vol 42, No. 152, 8 Aug 1977, pp 40123-40167.

2. Description:

This guide was prepared as part of an overall Soil Conservation Service (SCS) effort to refine and systematize the impact assessment part of planning. The material presented is a generalized guide for conducting environmental assessment. An introduction to selected analytical assessment techniques is also included. Evaluation criteria, detailed procedures, and technical standards were intentionally omitted. It was intended that SCS technical specialists establish these items for regional and local geographic areas in keeping with national standards for each technical field.

The appendixes to this guide include examples of (1) an impact matrix displaying environmental factors against potential alternatives, (2) a network diagram for analyzing probable environmental impacts, (3) a general checklist system for environmental evaluation, with accompanying text. A sample network diagram for the impacts of an impoundment is presented as Figure 1.

3. Applicability:

Although the information provided in this guide is general and undetailed, it could serve as a useful reference work for early planning studies. It is most relevant to describe base conditions and identify and trace impacts.

4. Advantages and Disadvantages:

Each of the techniques included in the SCS guidance has specific advantages and disadvantages and is covered elsewhere in this report.

5. Previous Uses:

6. Source/Contact:

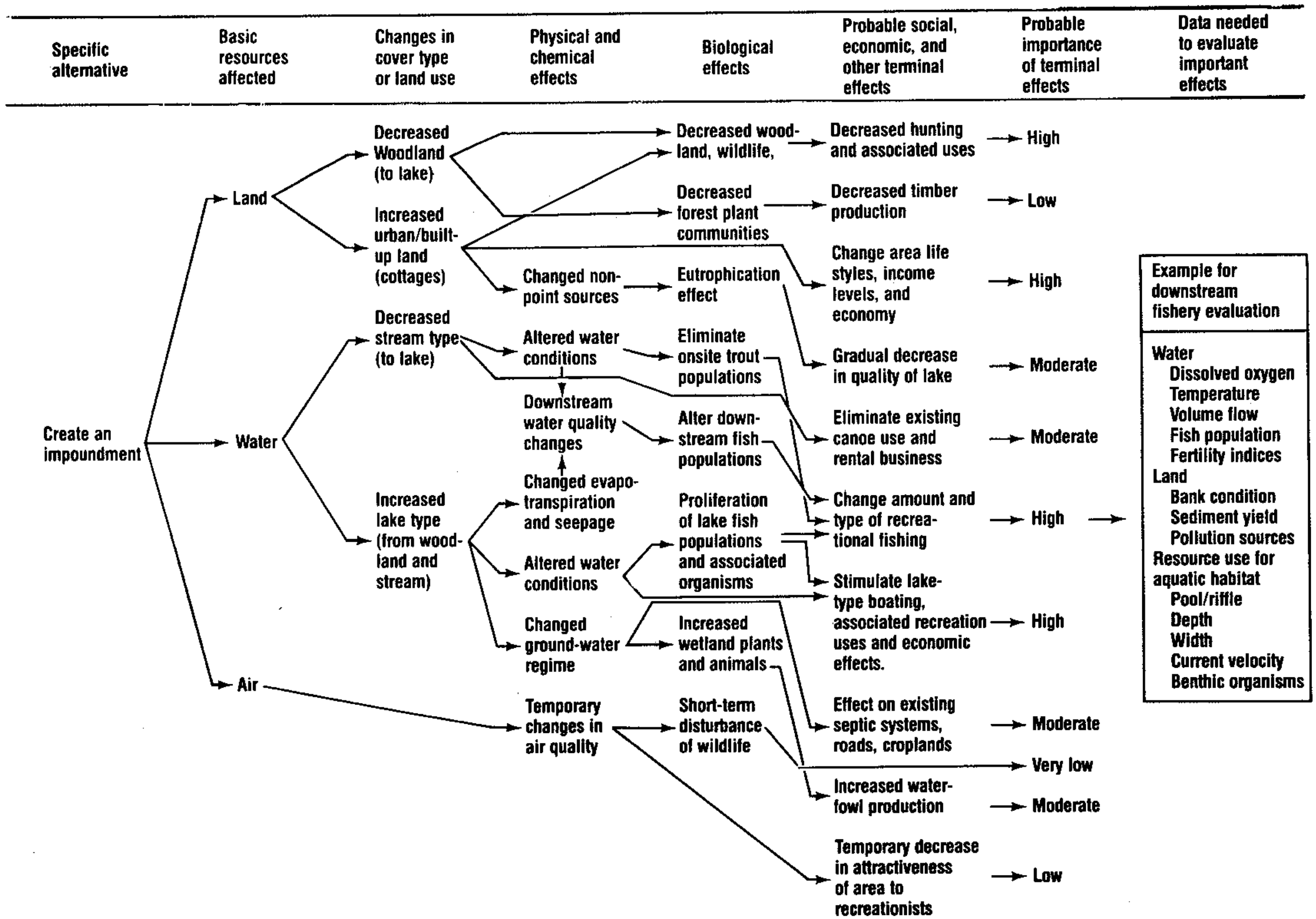


Figure 1. An Example of a Network Diagram for Analyzing Probable Environmental Impacts

1. Name:

Sorenson, Jens. 1971. A Framework for Identification and Control of Resource Degradation and Conflict in the Multiple Use of the Coastal Zone, M.S. Thesis, Department of Landscape Architecture, University of California, Berkeley, Calif.

2. Description:

This reference describes an approach to impact assessment which utilizes a set of stepped matrices to provide input to a network analysis. The initial matrix is similar to a Leopold type impact matrix to determine the impact of project activities on environmental resources. Successive matrices are used to determine how impacted resources may affect other resources, e.g., to determine secondary and higher order effects induced by project action.

The impacts identified through the matrix analysis are linked together to form a network analysis as in Figure 1. (The numbers in Figure 1 refer to entries in the impact matrices.) Analysis of the relationships and linkages in the network diagram provide a way to trace sources of impacts.

3. Applicability:

The analysis provided by this assessment framework is useful in organizing information about a project in a rational format which can be easily updated. The explicit nature of the matrices can serve to make clear the relationship between project actions and environmental impacts. Delineating the matrix relationships can serve to show where there is uncertainty about the impact of actions, thus serving as a guide for further study.

The stepped matrix network approach could conceivably be used for any stage planning study, but would provide the greatest benefit for later studies when alternatives are well developed and higher order impacts more readily assessed.

Sorenson's technique is sometimes referred to as the cause-condition-effect matrix technique, terminology which deviates somewhat from standard CE usage. The basis of a matrix analysis is that project actions or measures (cause) affect environmental resources and characteristics (condition) producing impacts (effect). Application of this technique would require minimal translation of terminology.

The stepped matrices network provides the framework for the Evaluation of Effects step.

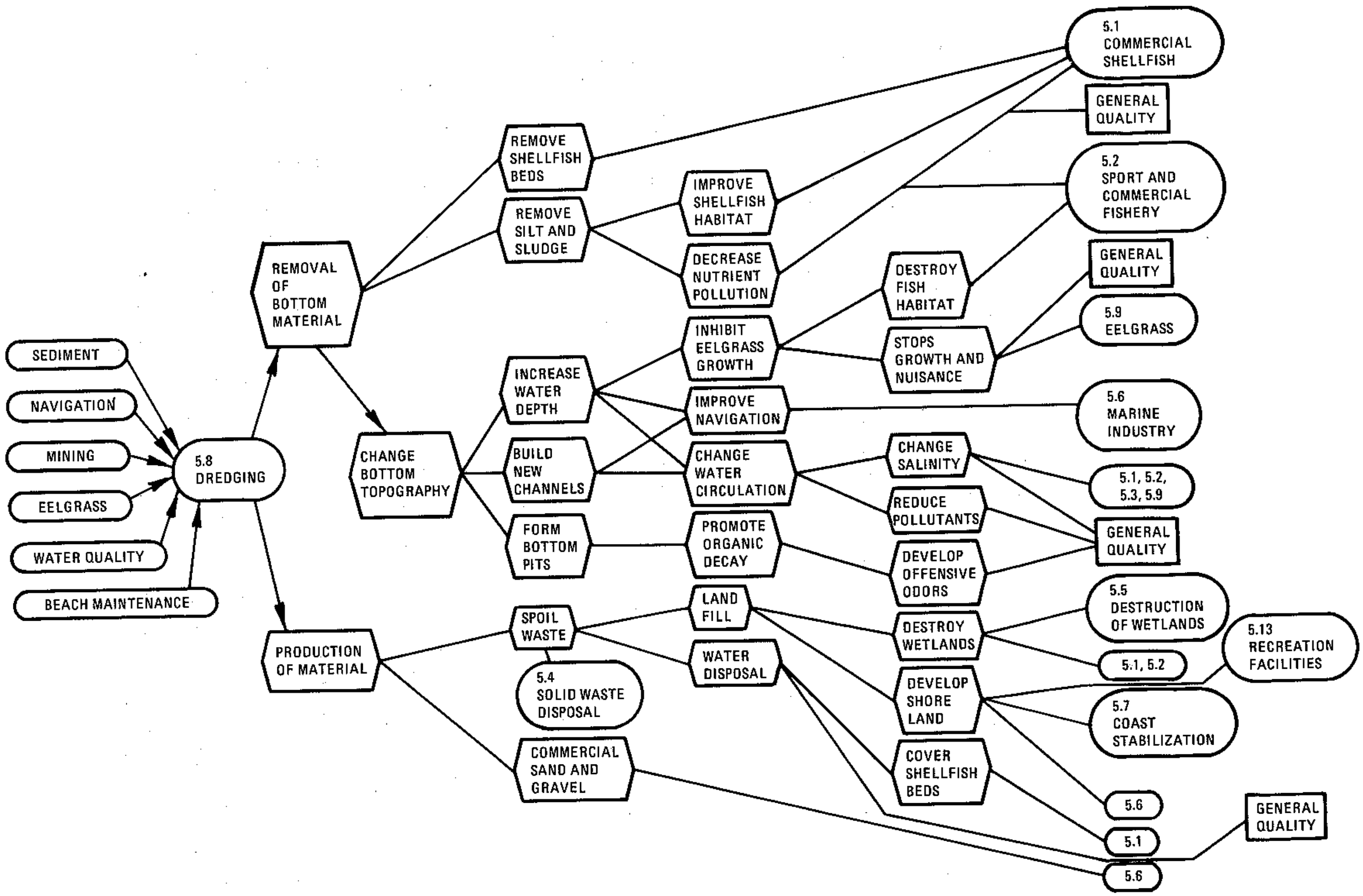


Figure 1. A Network Analysis of Dredging

4. Advantages and Disadvantages:

A chief advantage of this technique is its flexibility. Once established, the impact network and matrices may be updated to reflect current information or analyses. The stepped matrices examining higher order impacts are more useful than similar techniques employing a single matrix which may mask higher order impacts and important interrelationships.

5. Previous Uses:

6. Source/Contact:

1. Name:

States, James B. et al. 1978. "A Systems Approach to Ecological Baseline Studies," FWS/OBS-78/21, Energy Consultants, Inc., Fort Collins, Colo. (Prepared for Western Energy and Land Use Team, Fish and Wildlife Service.)

2. Description:

The purpose of this handbook on ecological baseline studies is to help resource planners systematically analyze ecosystems in order to identify expected impacts which require baseline studies. The authors expect such studies to enhance environmental planning, environmental impact statements, and post-impact monitoring programs. The three most important elements of the technique are the impact matrix, system process diagrams, and the system control diagrams. The authors propose five main steps in environmental assessment: identify perturbations, identify important components, identify important processes, develop an impact matrix, and develop system control diagrams.

Perturbations are identified by developing a matrix summarizing relationships between project activities and ecological processes. At this stage the types of relationships expected are limited to presence or absence. Perturbations are briefly documented as to their locations, time frames and durations, extents or scopes, and magnitudes using a standard one-page documentation form.

Important components are identified by determining (1) the appropriate level of detail shown by system elements, (2) the length of time required for field sampling in order to observe the total range of seasonal or other variations, (3) an appropriate set of geographically related "ecological response units" such as vegetative community types, and (4) a set of ecosystem components which aggregate flora and fauna compatibly with ecological response units, functional roles that they play, and the study objectives. Important processes are identified by (1) selecting flow currencies such as water, heat, or particular nutrients that underlie system processes, (2) drawing a flow diagram which shows presence of sources and sinks and transfers of flow currencies between ecosystem components, and (3) describing each flow in terms such as plant growth and aquatic plant photosynthesis.

Development of an impact matrix draws together and uses the results of earlier steps. This matrix has a column for each environmental perturbation and a row for each ecosystem component and process. The authors suggest completing each element of the matrix with a one, two, or three to indicate slight, moderate, or great concern about each effect. A standardized form is provided for brief documentation of reasons for each judgment about the effects.

Control diagrams are developed by (1) constructing a process diagram for each arrow on the flow diagram showing how the driving variables affect the level of that flow and (2) assembling the process diagrams into a total system control diagram using the modeling symbols provided. This step enables one to have an overview of the whole ecosystem and trace impacts through it.

3. Applicability:

This technique has elements, such as the impact matrix, which resemble aspects of other general assessment methodologies. This document advances the state-of-the-art by specifying an assessment process which results in systems analyses of the parts of the ecosystem. By completing such analyses, assessors develop a coherent and detailed basis for deciding which environmental attributes should be measured in ecological baseline studies. The effect of using the technique is to perform a systematic and detailed, paper-and-pencil systems analysis of project impacts. Such analyses are highly compatible with subsequent computer modeling of ecosystem dynamics although it is not mandatory for users to do so.

The ecosystem system analyses developed through use of this technique may be used to define base conditions for forecasting impacts. The systems analyses may be used in EQEP to model the functional aspects of the ecological attribute.

4. Advantages and Disadvantages:

Following this handbook does require considerable effort to design a baseline study. However, it may also allow avoiding some costly and irreparable mistakes later on.

Planners can also benefit from a cursory application of the technique when constraints prohibit various detailed analyses. Systematically describing what is known about system processes is desirable as is the technique's tendency to force users to acknowledge the system interactions that they are unable to describe.

5. Previous Uses:

The larger portion of this report documents an application of the assessment technique to the Coal Project, Western Energy and Land Use Team, Fish and Wildlife Service. The focus of this application was on oil shale development.

6. Source/Contact:

Peter T. Haug, Bureau of Land Management, 925 S. County Rd. 5, Fort Collins, Colo. 80524

James B. States, Battelle PNL, P. O. Box 999, Richland, Wash. 99352

1. Name:

U. S. Army Engineer District, Tulsa, CE. 1972. "Matrix Analysis of Alternatives for Water Resource Development," Draft Technical Paper, Tulsa, Okla.

2. Description:

This is an evaluation technique which displays environmental analysis information in a matrix format. This technique evaluates the contributions of alternatives to environmental quality by utilizing a weighting-scaling approach. Because this was developed prior to publication of the 1973 Principles and Standards, the draft paper refers to three planning objectives--environmental quality, human life quality, and economics--rather than the NED and EQ objectives. A simple Fortran program is included to determine if significant differences exist in the net impacts of alternatives under each objective. This technique is designed to evaluate comparable alternatives, that is, alternatives which affect the same resources. Up to ten alternatives, including the no-action alternative, may be considered by the program as it is presently written. A matrix for each planning objective or account is produced (see Table 1) which shows the impacts on the parameters included in each account so that trade-offs between alternatives are displayed.

For each planning objective or account, the alternatives are compared by producing weighted scores for the impacted variables. The parameters are arranged in a hierarchical manner. Weighting factors are assigned for each level of the hierarchy. The parameters are weighted by the apportioning of 100 points among the several broad categories in the account (Table 1). Successive levels of the hierarchy within each broad category are weighted by apportioning 1.00. Equivalency factors for each of the parameters are calculated. Equivalency factors are the product of the weighting factors assigned at each level of the hierarchy for the parameter.

Data produced from the Assessment of Effects are utilized to assign raw scores to each of the variables. Raw scores are assigned on the basis of relative impact of the alternative on the variable. The no-action alternative is assigned a raw score of 0. The alternative with the greatest impact is assigned a raw score of +5 or -5 depending on the direction of the impact. Other alternatives are assigned values between -5 and +5 depending on their relative impacts.

Weighted scores are produced for each of the measured variables by multiplying the equivalency score by the raw score. The weighted scores are summed for the variables. The alternatives may then be ranked for each objective on the basis of the sum of the weighted scores.

Through the use of the Fortran program, it is possible to determine if statistically significant differences exist between the impacts of the alternatives being evaluated.

Parameters	Weighting Factors				Equivalency Factor	Alternative A Raw Score	Alternative A Weighted Score	Alternative B Raw Score	Alternative B Weighted Score	Alternative C Raw Score	Alternative C Weighted Score	Alternative D Raw Score	Alternative D Weighted Score
I. Unique, Rare, or Unusually Important Species	20												
A. Fauna		0.80			16.00	+1	+16.00	+2	+32.00	-3	+48.00	+5	+80.00
B. Flora		0.20			4.00	+2	+8.00	+1	+4.00	-1	-4.00	+5	+20.00
II. Plant and Animal Habitat	40												
A. Aquatic		0.40											
1. Lotic (flowing)			0.90										
a. Quality				0.70	10.08	+1	+10.08	+3	+30.24	+2	+20.16	+5	-80.40
b. Quantity				0.30	4.32	-5	-21.60	-2	-8.64	-2	-8.64	0	0.00
2. Lentic (standing)			0.10										
a. Quality				0.70	1.12	+2	+2.24	+4	+4.48	+5	-5.60	0	0.00
b. Quantity				0.30	0.48	+4	+1.92	+5	+2.40	-5	+2.40	0	0.00
B. Terrestial		0.60											
1. Grassland, Pasture, and Cropland			0.20										
a. Quality				0.70	3.36	-2	-6.72	-3	-10.08	-3	-10.08	+5	+16.80
b. Quantity				0.30	1.44	+4	+5.76	+2	+2.88	-5	+7.20	0	0.00
2. Woodland			0.80										
a. Quality				0.70	13.44	+1	+13.44	+2	+26.88	+3	+40.32	+5	+67.20
b. Quantity				0.30	5.76	-	-23.04	-2	-11.52	-5	-28.80	0	0.00
III. Ecosystem Diversity and Stability	20												
A. Aquatic		0.40			8.00	+3	+24.00	+4	+32.00	+5	-40.00	+1	+8.00
B. Terrestial		0.60			12.00	-2	-24.00	-3	-36.00	-4	-48.00	+5	+10.00
IV. Ecosystem Productivity	20												
A. Aquatic		0.40			8.00	+3	+24.00	+5	+40.00	+4	-32.00	0	0.00
B. Terrestial		0.60			12.00	-4	-48.00	-4	-48.00	-5	-60.00	0	0.00
IMPACT ON NATURAL ENVIRONMENT						-17.92		+60.64		+36.16		+302.40	
RANK							4		2		3		1

Table 1

Matrix Analysis of Alternatives, Environmental Quality Parameters

3. Applicability:

This approach to impact evaluation may be used during any planning stage after impact projections have been made.

4. Advantages and Disadvantages:

Although this methodology has many strengths, consultation with personnel in the Tulsa District indicates that its use was discontinued because of the costliness in time to prepare data and the fact that the output proved difficult for publics to interpret.

5. Previous Uses:

This impact matrix was used in a number of Tulsa District studies subsequent to its development.

6. Source/Contact:

1. Name:

U. S. Army Hydrologic Engineering Center, CE. 1978. "Generalized Computer Program Users Manual: Resource Information and Analysis," Computer Program 401-X6-L7590, Davis, Calif.

U. S. Army Hydrologic Engineering Center, CE. 1978. "Guide Manual for the Creation of Grid Cell Data Banks," Davis, Calif.

2. Description:

The Resource Information and Analysis Program (RIA) was designed to perform selected geographic and environmental analyses using base data that are in a grid-cell data bank format. The data banks required for RIA can be created in one of two ways: using grid cells or x,y coordinates. The grid cell approach is the simplest. The x,y (polygon) approach uses point coordinates to define the locations and boundaries of points, lines, and areas describing geographic variation. The latter approach is much more time intensive. The grid cell was chosen because grid cells provide an easy method for collecting and organizing data. Computer storage of the encoded data is straightforward, editing of stored data is easy, the cells are able to accommodate both discrete and continuous data, cell coordinates are easily translated for graphic output, and point data can be directly located using grid cell interpolation.

The manner in which the grid cell data base is initially formulated determines the degree of specificity that can be achieved by the analysis procedures. The grid cells represent a grid pattern (selected by the user) that is laid over a base map, e.g., a topographic map. Data, whether nominal, ordinal, or interval, are entered into each cell; and each type of data is accompanied by an input legend. The completed cells, then, are entered into the data base using a system of row and columnar coordinates and become the data base map. It is important to note that any given data base may contain only one grid cell size and shape.

Single data variables, e.g., land use type, require the entry of only one set of base map coordinates and cell values. Multidata variables, e.g., weighted or scaled values, require the entry of a series of base map coordinates and cell values that are computationally synthesized to become a single computerized data base map. Editing of data files -- data entry, modification, transformation, or deletion -- can be undertaken as needed, whether during initial analyses or for updating the study at some later date.

The RIA can perform four major types of analyses, which generate either computer printer graphics or tabulations of the analysis or both. The four major types of analysis are:

a. Distance Determination

b. Impact Assessment

c. Locational Attractiveness

d. Coincident Tabulation

The Distance Determination procedure calculates the linear distance of one grid cell from another cell containing a data variable of interest. The computation of intercell distances can be performed for a single data variable or a combination of two or more data variables. Each cell within the data base possesses a set of coordinates that define the central point of that cell. Using the central point coordinates for two or more cells, the Distance Determination package computes the geometric distance between cell central points.

The Impact Assessment procedure is designed to highlight areas of high environmental "impact potential" caused by an activity. The computed potential impact is not an absolute quantifiable representation of the actual impact, but represents a range of impact in relative terms. The computation of impacts is accomplished by mapping the combination of variables within cells, which results in a computerized overlay of potential impacts. The degree of impact is denoted by the categories: Extreme, Severe, Moderate, Slight, or Null. The more dense the overlay the greater the potential for impact.

The Locational Attractiveness procedure is used to develop an index value for each grid cell based on specific combinations of data variables within the data base. The values that are computed represent the relative attractiveness of each grid cell for a specified activity. Locational attractiveness is an extension of McHarg's overlay technique, only converted to computer use. Each data variable is scaled from 1 to 10, with 10 being the most attractive component. The index values are computed using these scalar values.

The Coincident Tabulation procedure develops an accounting for the coincidence of two data variables. One application of this procedure might be to determine the shifts of variables over time by using two variables that represent, say, land use or vegetative cover, at two points in time. The results can be tabulated for a specified geographic area.

A mapping procedure produces line printer graphics of the analyses. The mapping procedure offers the benefit of providing the user with the opportunity to simply input items that are considered of importance to the analysis at hand, but the user need not input grid coordinates. This results in a significant savings in terms of program input effort. The mapping procedure produces single character printed graphics, which, when layered, produces a shading effect for each intensity category specified by the user.

3. <u>Applicability</u>:

The data management and computation capabilities available with the RIA program provide a method for effectively managing data sets for large areas. The capability for use of the program, storing the results, and then later updating the data base make it valuable to use in successive planning iterations.

4. <u>Advantages and Disadvantages</u>:

The RIA program is a very flexible software package. There are no limitations on the types of available analyses that may be performed in a single computer run. The results of prior analyses can be stored as part of the data base for later computational use. The data base can be stored on magnetic tape, disc, or punched cards. The only software limitations are that the number of columns used in establishing the data base is restricted to 1,000, and the maximum number of variables handled, ranging from 2 (Impact Assessment) to 8 (Locational Attractiveness). The RIA program was developed for the Control Data 7600 computer system, but can be adapted to other systems with comparable hardware characteristics.

The major disadvantages of grid cell representations of mapped data are:

a. The loss of resolution caused by the restructuring of data to fixed grid cell boundaries. Resolution increases as the size of grid cells decrease, but cost also increases.

b. Sinuous features, e.g., rivers and boundaries, are not easily translated to grid cell requirements. (The larger the cell the greater the distortion).

c. Imprecision arises from the need to interpolate data when more than one variable falls within a single grid cell.

For most users, the efficiency of grid cell analysis more than compensates for the loss of resolution. In cases where very high accuracy of map quality is required, x,y coordinate systems should be used.

The grid cell system can provide a basis for the integration of data from various sources, e.g., field work, literature reviews, and remote sensing. In the case of remotely sensed data, grid cell systems offer an opportunity for the rapid translation of aerial photography or satellite imagery to base maps once ground truths and interpretative keys have been established.

A primary factor in the selection of the grid cell approach for Corps planning applications must be the cost-effectiveness of the technique. The development of the grid cell data base is time consuming and its accuracy is largely a function of the interpolative skills of those assigned to the task of translating spatial data or phenomena to values within individual grid cells.

5. Previous Uses:

6. Source/Contact:

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1. Name:

U. S. Fish and Wildlife Service. 1979. "Classification of Wetlands and Deepwater Habitats of the United States," FWS/OBS-79/31, Office of Biological Services, Fish and Wildlife Service, Washington, D.C.

2. Description:

This report describes the wetlands classification scheme developed for adoption by Fish and Wildlife Service and to be utilized in the National Wetlands Inventory (NWI). Use of the classification scheme is intended to provide uniformity in the identification, classification, and mapping of wetlands. The various types of wetlands and deepwater habitats are arranged in a hierarchial structure. The hierarchy is composed of three elements or levels: systems, subsystems, and classes.

Definitions and criteria used to classify a specific wetland or deepwater habitat are presented for each element of the classification scheme. Five systems are included in the scheme:

a. Marine

b. Estuarine

c. Riverine

d. Lacustrine

e. Palustrine

The systems are divided into subsystems on the basis of inundation characteristics, e.g., subtidal or intertidal (except for Palustrine, which has no subsystems). The wetland class is determined by the substrate material and vegetative types.

This classification scheme makes use of so-called modifiers to describe the classes. Modifiers are used to describe water regime, water chemistry, and soil characteristics of the classes.

3. Applicability:

The use of this wetlands classification system can provide consistency in the inventory and classification of wetlands. The hierarchical structure of the classification scheme allows it to be utilized at varying levels of specificity dependent on the purpose of classification and quality of available data, e.g., resolution of remote sensing data.

4. Advantages and Disadvantages:

This wetlands classification system is a systematic, scientifically defensible, and tractable method to identify characteristics of wetlands. However, utilizing the definitions and criteria set out may require field data not available at a specific point in time.

5. Previous Uses:

The National Wetlands Inventory is utilizing this classification scheme for classifying and mapping wetlands throughout the United States.

6. Source/Contact:

Questions about NWI or specific applications of this classification scheme should be addressed to the Regional Wetlands Coordinator in the appropriate FWS regional office.

1. Name:

Yorke, Thomas H. 1978. "Impact Assessment of Water Resource Development Activities: A Dual Matrix Approach," FWS/OBS-78/82, Eastern Energy and Land Use Team, U. S. Fish and Wildlife Service, Kearneysville, W. Va.

2. Description:

This report presents a matrix approach to identifying the impacts of water resource development.

This report restricts itself to channel modification developments. The method was developed by the Fish and Wildlife Service to assist in identifying impacts to biota which result due to channel modification. The basis for the dual matrix approach is that the response of biota to changes in physical-chemical parameters is the same regardless of the type of development causing the change. Because of this, the Dual Matrix utilizes the following tasks:

a. Identification of physical-chemical changes which result from typical water resources development activities.

b. Identification of the effects the physical-chemical changes have on such parameters as community structure, benthos, riparian vegetation, and other floral and faunal environmental parameters.

The subject report only covers the first of the above tasks. The second task is to be accomplished through an extensive literature survey and computerization of the system. This second task has, as yet, not been accomplished.

The water resource development activities considered in this report are:

a. Channel enlargement.

b. Channel realignment.

c. Clearing and snagging.

d. Dikes and jetties.

e. Bank stabilization.

f. Floodplain clearing.

g. Flood protection levees.

h. Flood control impoundments.

i. Hydroelectric impoundments.

j. Locks and dams.

k. Diversion dams.

l. Transbasin augmentation.

For each of the development activities, the physical-chemical changes are described in qualitative terms. Because the development activities considered all deal with stream channel modification of some sort, the physical-chemical changes identified relate to water quality and streambed characteristics. The physical-chemical characteristics considered are:

a. Depth and stage.

b. Surface area.

c. Channel configuration.

d. Velocity.

e. Temperature.

f. Suspended solids.

g. Bed materials.

h. Dissolved substances.

i. Light transmissivity.

j. Flow variability.

3. Applicability:

This report provides an overview to the major impacts of channel modification. The identification of changes in the physical-chemical characteristics caused by stream modification allows the planner to progress to the second matrix, that is, determining how the physical-chemical changes will affect the fish and wildlife in the stream area.

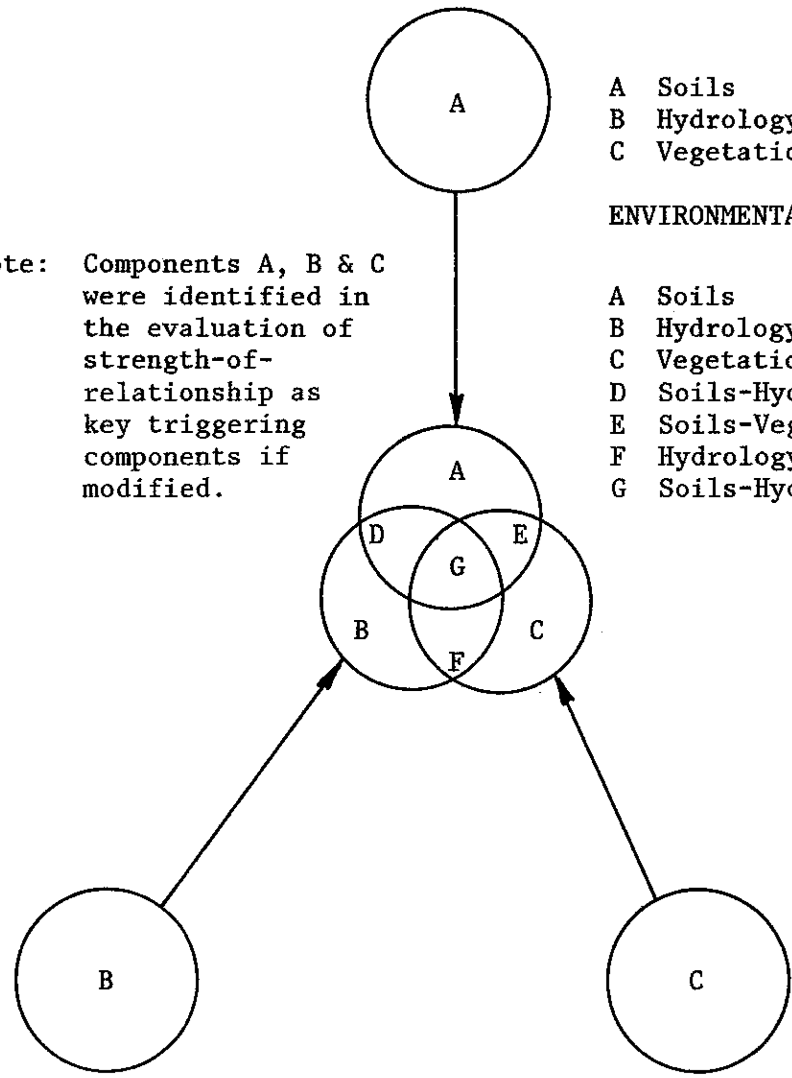
4. Advantages and Disadvantages:

In its present form (without the supporting second matrix documentation), this report provides an overview of the gross physical-chemical impacts which are the result of stream modification. This approach is limited because the second matrix documentation, relating physical-chemical changes to flora and fauna, has not been published.

5. Previous Uses:

6. Source/Contact:

EXTENDED PROFILE SECTION-METHODS



COMPONENTS

A Soils
B Hydrology
C Vegetation

ENVIRONMENTAL RESPONSE UNITS

A Soils
B Hydrology
C Vegetation
D Soils-Hydrology
E Soils-Vegetation
F Hydrology-Vegetation
G Soils-Hydrology-Vegetation

Note: Components A, B & C were identified in the evaluation of strength-of-relationship as key triggering components if modified.

Alden Figure 1. Spatial Distribution of Environmental Response Units

Environmental Response Unit (ERU)	Significant Relationship with Other Components
A. Soils (high erosion potential)	Evapotranspiration, Runoff, Microclimate-temperatures, Microclimate-moisture, Wildlife-mammals, Wildlife-birds, Hydrology, Vegetation, Fish Habitat,* Wildlife Habitat*
B. Hydrology (high value for runoff)	Vegetation, Limnology-biological factors, Surface soils, Recreation Resources-existing, Scenery-foreground, Scenery-middleground, Fish Habitat,* Fish species-trout,* Recreation Resources-potential*
C. Vegetation, riparian and meadow (high value-rare to unusual vegetative type)	Surface Soil, Runoff, Surface Hydrology, Wildlife-birds, Wildlife-mammals, Scenery-foreground, Scenery-middleground, Air Drainage, Microclimate-temperature, Microclimate-moisture, Snowdrift Pattern, Evapotranspiration, Wildlife Habitat,* Fish Habitat*
D. Soils-Hydrology	Evapotranspiration, Microclimate-temperature, Microclimate-moisture, Wildlife-birds, Hydrology, Vegetation, Limnology-biological factors, Surface Soils, Recreation Resources-existing, Recreation Resources-potential, Scenery-foreground, Scenery-middleground, Wildlife Habitat,* Wildlife-mammals,* Fish Species-trout,* Runoff,** Fish Habitat***
E. Soils-Vegetation	Runoff, Vegetation, Surface Soil, Air Drainages, Snowdrift Pattern, Fish Species-trout,* Evapotranspiration,** Microclimate-temperature,** Microclimate-moisture,** Fish Habitat,** Wildlife-mammals,** Wildlife-birds,** Hydrology,** Wildlife Habitat***
F. Hydrology-Vegetation	Vegetation, Limnology-biological factors, Recreation Resources-existing, Runoff, Hydrology, Wildlife-mammals. Wildlife-birds, Air Drainage, Microclimate-temperature, Microclimate-moisture, Snowdrift Pattern, Evapotranspiration, Fish Species-trout,* Recreation Resources-potential,* Wildlife Habitat,* Surface Soils,** Scenery-foreground,** Scenery-middleground,** Fish Habitat***
G. Soils-Hydrology-Vegetation	Limnology-biological factors, Recreation Resources-existing, Air Drainage, Snowdrift Patterns, Fish species-trout,* Recreation Resources-potential,* Evapotranspiration,** Runoff,** Microclimate-moisture,** Microclimate-temperature,** Wildlife-mammals,** Wildlife-birds,** Hydrology,** Vegetation,** Surface Soils,** Scenery-foreground,** Scenery-middleground,** Fish Habitat,*** Wildlife Habitat***

* = most sensitive environmental components.
** = increased opportunity for high negative impact.
*** = combined increased opportunity for high negative impact and most sensitive environmental components.

Alden Table 2. Relationships of ERU

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Figure 1 - Canter

Example of a Ranking Checklist

	Alternatives							
	A-1	A-2	A-3	B	C-1	C-1a	C-2	D
Project Objectives:								
Provide an institutionally acceptable wastewater disposal system for the citizens of Jacksonville.	3-4	3-4	1	2	2	3-4	3	4
Environmental Objectives:								
Minimize the adverse effects of wastewater treatment and disposal.	1	1	1	2	2	2	2	4
Minimize the social/economic cost of wastewater treatment and disposal.	3	3	1	3	2	2	3	4
Provide for the reuse of treated wastewater.	4	4	3	1	1	1	3	4
Maintain the historical quality of Jacksonville	3	3	2	2	2	1	2	1

Key:

1 Best
2 Second best
3 Limited
4 Fails

Source: Environmental Protection Agency. Final Environmental Impact Statement for City of Jacksonville, Jackson County, Oregon, Seattle, Wash.

CANTER

Figure 2 - Canter

Example of a Scaling Checklist

Potential Impacts	Alternatives* 1	134	166	170	171	No Action
Physical/Biological Impacts						
Archaeological resources	P	P	P	P	P	N
Air quality	A	A	A	A	A	A
Soils and crops	N	P	P	P	P	N
Agricultural practices	N	P	P	P	P	N
Seismic risks	A	A	A	A	A	A
Groundwater quality	N	B	B	B	P	A
Surface-water quality	B	B	B	B	B	A
Monterey Bay water quality	B	B	B	B	B	A
Water supply and reuse	N	B	B	B	B	N
Public health - water contamination	N	B	B	B	P	A
Public health - land contamination	N	A	A	A	A	N
Energy consumption in treatment and disposal of wastewater (rank).	2	6	6	4	3	1
Aesthetics	B	B	B	B	B	A
Land-use changes	N	A	P	A	A	N
Salinas River biota	A	P	A	A	A	N
Salinas River lagoon biota	P	B	P	P	P	P
Marine biota	B	B	B	B	B	N
General construction impacts (rank)	A	A	A	A	A	N
Economic Impacts						
Construction cost (rank)	3	5	4	6	2	1
Operating cost (rank)	2	6	3	5	3	1
Local cost (rank)	3	5	4	6	2	1
Overall cost (rank)	3	5	4	6	2	1
Social Impacts						
Growth inducement-accommodation	A	A	A	A	A	N
Local acceptance	A	P	P	P	P	A

* Key:

B Beneficial
A Adverse
P Problematical (unknown or open to question)
N None
Comparative ranking from most acceptable (1) to least acceptable (6) alternative.
Ranking does not consider possible economic penalties for noncompliance with Central Coastal Regional Water Quality Control Board and National Pollutant Discharge Elimination System permits.

Source: Environmental Protection Agency and Monterey Peninsula Water Pollution Control Agency. Final Environmental Impact Statement and Environmental Impact Report, North Monterey County Facilities Plan, Vol I. San Francisco, August 1977.

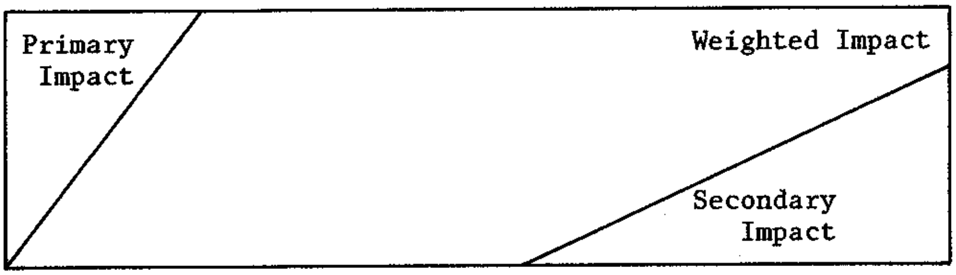
CANTER

Figure 3 - Canter

Example of a Weighting-Scaling Checklist

Significant Assessment Categories	Proposed Project	Alternative A-1	Alternative A-2	Alternative A-3	Alternative A-4	Alternative A-5	Alternative A-6	Alternative A-7	Weighting Factor
NATURAL ENVIRONMENTAL VALUES									
Air Quality (localized)	-1 / 0 / 1	-2 / -1 / 1	-1 / -2 / -1	-1 / -3 / -2	-1 / -3 / -2	-1 / -2 / -1	-1 / 0 / 1	0 / -3 / -2	1
Water Quality (surface)	3 / 3 / -2	3 / 6 / -1	3 / 6 / -1	3 / 6 / -1	3 / 6 / -1	3 / 3 / -2	3 / 6 / -1	-2 / -6 / -1	3
Water Quality (ground)	0 / 4 / 2	0 / 2 / 1	0 / 2 / 1	0 / 2 / 1	0 / 2 / 1	0 / 4 / 2	0 / 0 / 0	0 / -4 / -2	2
Wildlife	-4 / -10 / -2	0 / 0 / 0	-1 / -4 / -1	-1 / -4 / -1	-1 / -4 / -1	-1 / -4 / -1	0 / 0 / 0	0 / 0 / 0	2
Fisheries	-1 / 0 / -1	1 / 4 / 1	1 / 4 / 1	1 / 4 / 1	1 / 4 / 1	1 / 0 / -1	1 / 4 / 1	2 / 6 / -1	2
Vegetation and Habitat	-1 / -6 / -2	0 / 0 / 0	-1 / -4 / -1	-1 / -4 / -1	-1 / -4 / -1	-1 / -4 / -1	0 / 0 / 0	0 / 0 / 0	2
Rare and Endangered Species	-1 / -1 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	1
Natural Hazards	-1 / -3 / -2	-1 / -1 / 0	-1 / -2 / -1	-1 / -2 / -1	-1 / -2 / -1	0 / -2 / -2	-1 / 1 / 0	0 / 0 / 0	1
TOTAL	-13	10	0	3	3	-5	9	-19	
ECONOMIC									
Local Capital Cost	-2 / -4 / 0	-1 / -2 / 0	-3 / -6 / 0	-2 / -4 / 0	-2 / -4 / 0	-2 / -4 / 0	-1 / -6 / -2	0 / -6 / -3	2
O & M Cost	-1 / -2 / 0	-3 / -6 / 0	-3 / -6 / 0	-1 / -2 / 0	-1 / -2 / 0	-1 / -2 / 0	0 / 0 / 0	0 / 0 / 0	2
Induced Development Costs	0 / -6 / -3	0 / -2 / -1	0 / -2 / -1	0 / -2 / -1	0 / -2 / -1	0 / -6 / -3	0 / 0 / 0	0 / 0 / 0	2
Individual Cost	-1 / -2 / 0	-2 / -2 / 0	-3 / -6 / 0	-1 / -2 / 0	-1 / -2 / 0	-1 / -2 / 0	0 / -4 / -2	0 / -6 / -3	2
Loss of Ag. Productivity	0 / -8 / -4	0 / 0 / 0	0 / -2 / -1	0 / -2 / -1	-1 / -6 / -2	-1 / -8 / -3	0 / 0 / 0	0 / 0 / 0	2
	-22	-12	-22	-12	-16	-22	-10	-12	
SOCIAL-CULTURAL									
Historic-Archaeological	-1 / -3 / -2	0 / -1 / -1	0 / -1 / -1	0 / -1 / -1	0 / -1 / -1	-1 / -3 / -2	0 / 0 / 0	0 / 0 / 0	1
Public Acceptability	-2 / -3 / -1	-1 / -1 / 0	-2 / -2 / 0	-1 / -1 / 0	1 / 1 / 0	-1 / -2 / -1	0 / -1 / -1	-2 / -4 / -2	1
Regulatory/Legal	-1 / -6 / -2	1 / 4 / 1	1 / 4 / 1	1 / 4 / 1	1 / 4 / 1	1 / -2 / -2	1 / 2 / 0	2 / 6 / -1	2
Cultural Pattern (life style)	0 / -4 / -2	0 / 2 / 1	0 / 2 / 1	0 / 2 / 1	0 / 2 / 1	0 / -4 / -2	0 / 0 / 0	-1 / -2 / 0	2
Aesthetics Values	-1 / -6 / -2	-1 / 0 / 1	0 / 2 / 1	0 / 2 / 1	0 / 2 / 1	0 / -4 / -2	-1 / -2 / 0	-2 / -4 / 0	2
Recreational Values	-1 / -2 / -1	1 / 1 / 0	1 / 1 / 0	1 / 1 / 0	1 / 1 / 0	1 / 0 / -1	1 / 0 / -1	0 / -1 / -1	1
TOTAL	-24	6	6	7	9	-16	-1	-17	
LAND USE PLANNING									
Adherence to the Planning Proc.	0 / -6 / -3	0 / 6 / 3	0 / -4 / -2	0 / -4 / -2	0 / -4 / -2	0 / -6 / -3	0 / -8 / -4	0 / -6 / -3	2
Growth Inducement	0 / -6 / -3	0 / 6 / 3	0 / -4 / -2	0 / -4 / -2	0 / -4 / -2	0 / -8 / -4	0 / -1 / 1	0 / 0 / 0	2
Growth Regulation	0 / -6 / -3	0 / 6 / 3	0 / 6 / 3	0 / 6 / 3	0 / 4 / 2	0 / -6 / -3	0 / 4 / 2	0 / -1 / -1	2
	-18	18	-2	-2	-4	-18	-3	-7	

Key:



The rationale for the assigned impact scale values is as follows:

+5 Major long-term, extensive benefit (highest possible rating)
+4 Major benefit, but characterized as either short-term or of limited extent
+3 Significant benefit, either long-term affecting a limited area or short-term affecting an extensive area
+2 Minor benefit, but of a long-term or extensive nature
+1 Minor benefit affecting a limited area
0 No impact
-1 Minor adverse effects affecting a limited area
-2 Minor adverse effects, but of a long-term or extensive nature
-3 Significant adverse effects, either long-term affecting a limited area or short-term affecting an extensive area
-4 Major adverse effects, but characterized as either short-term or of limited extent
-5 Major long-term, extensive adverse effects (lowest possible rating)

The weighting factors are determined as follows:

1. Little, if any extraordinary significance in the project area (e.g., no significant wilderness resource per se exists in the project area or is affected by the proposed project)

2. A significant consideration in the project area (e.g., the South Park Elk Feedground)

3. An extraordinary significance in the project area (e.g., treated effluent discharges)

The number in the center of each rectangle is the product of the weighting factor times the primary plus secondary impact ratings.

CANTER

1. Name:

Carss, Brian W. 1979. "Conducting Interpretive Structural Modeling (ISM) Without a Computer."

2. Description:

Because a computer terminal, telephone hookup, and timeshared computer may be costly or unavailable for holding of ISM group exercises, this paper-and-pencil technique can serve either as an alternative or as a backup resource in case of computer failure. Readers unfamiliar with ISM are advised to examine the Lendaris Profile before reading this profile. The following sections describe how to manually record ISM sessions.

ISM Session Set Up

It is assumed that the group that is about to engage in an ISM session has already gone through the necessary preliminary work of establishing an element set and an appropriate relational statement (see Lendaris). Overhead projection slides (OHP) are prepared with the relational statement set out so that the individual elements, which were also on an OHP cut into strips, can be overlaid to give a completed statement.

The organization of the participating group is such that the participants can all see each other easily and the overhead projector does not intrude into the group. A horseshoe shape arrangement has worked very well. A relaxed atmosphere is important as a stimulus to free exchange of opinions during the discussions.

Ideally, two people are needed to manage a session. One person to act as a recorder and the other as a facilitator. The facilitator, as well as changing the elements for discussion on the OHP, also "orchestrates" the discussion so that all opinions are heard and no one person dominates the group. The facilitator also is responsible for sensing when the working group has reached a consensus or is ready to vote.

Recording the ISM Session

In order to ease the burden of keeping track of what decisions need to be made, it is important that each element be given an identification number and that the number should appear alongside the element. For example, if the elements are tentative planning objectives, 7 might be "to enhance water based recreation" and 16 might be "to retard stream bank erosion" within the study area. Having numbers attached to each element makes it easy to refer to the elements.

The recorder needs to work on lined 8-1/2- by 14-in. paper or larger and write all of the element numbers side by side across the middle of the page as in Diagram 1.

Identification Date

1 2 3 4 5 6 7 8 . . . .

Diagram 1

It is good practice to label each sheet with some unique identification and the date.

In order to illustrate how the manual recording technique works it is necessary to give an example relational statement.

"Within the XXX Corps study area fulfillment of" (objective m)

"Contributes to fulfillment of" (objective n)

In the first instance, the recorder calls for elements (objectives) 1 and 2 to be put in place on the OHP (m=1, n=2). Of course, any type of elements other than objectives can be used as appropriate.

If the group reaches consensus and decides that the statement is true, then Diagram 1 is modified as shown in Diagram 2. In other words,

Identification Date

2

1 ~~2~~ 3 4 5 6 7 8 . . . .

Diagram 2

they determined that fulfillment of objective 1 contributes to fulfillment of objective 2, which is recorded as in Diagram 3. The numeral 2

Identification   Date

2 3

1 ~~2~~ ~~3~~ ~~4~~ = 5 ~~6~~ ~~7~~ ~~8~~

4 6 7 8

<u>Diagram 3</u>

is crossed out of the original line and placed halfway between this line and the top or the bottom of the page, as the case may be. Numbers are placed below the original line whenever statements are false. The session then proceeds to consider the pairs of elements 1 and 3; 1 and 4; 1 and 5; until the final comparison 1 and n is reached.

The recording sheet may well look like the following at this point. Notice that an equal sign (=) has been placed before element (objective) 5. This is to indicate that elements 1 and 5 were specified as being equivalent and therefore element 1 would not precede element 5 and vice versa.

The ISM session participants continue to consider elements 2 and 3, showing which objective supports the other. Similarly, elements 4, 6, 7 and 8 are also put into order. The final hierarchical arrangement may well appear as shown in Diagram 4a. This final ordering can be displayed as in the directed graph, Diagram 4b. This diagram states that objectives 1 and 5 are equivalent, that 3 contributes to 2, that 2 contributes to 1 and 5, that 1 and 5 contribute to 6, etc. Objective 3 is an umbrella objective subsuming all others. Objective 8 is the most general and least specific.

Identification Date

3

2 ~~3~~

1 ~~2~~ ~~3~~ ~~4~~ = 5 ~~6~~ 7 ~~8~~

6 7

7

4 ~~6~~ 7 ~~8~~

8

Diagram 4a.

3
2
1 = 5
6
7
4
8

Diagram 4b.

The procedure, as outlined so far, accounts for the situations where the completed relational statement is true, false, or where the elements are considered to be equivalent. One other possibility exists, and that is where the elements cannot be directly compared. Often the situation arises where the two elements under consideration represent such very different facets of the problem that it would stretch the imagination to begin to make any comparison. It is a bit like trying to compare apples and automobiles.

When the ISM participants decide that a pair of elements cannot be compared, the recorder places the number of the second element at the far right-hand side of the page on the same line. Any additional elements that cannot be compared would follow in the same way. These elements will be considered separately when the main hierarchy has been established.

The elements that appear on the right of the recording sheet are treated as a normal group of elements to be mutually compared. The ISM participants attempt to place these elements into a subhierarchy which can then be spliced into the main one.

In the simplest case, where all of the noncomparable elements form a subhierarchy of their own, one proceeds to take the top most element and make a comparison with an element at every level of the hierarchy until a fit is found. For example, consider the situation in Diagram 5.

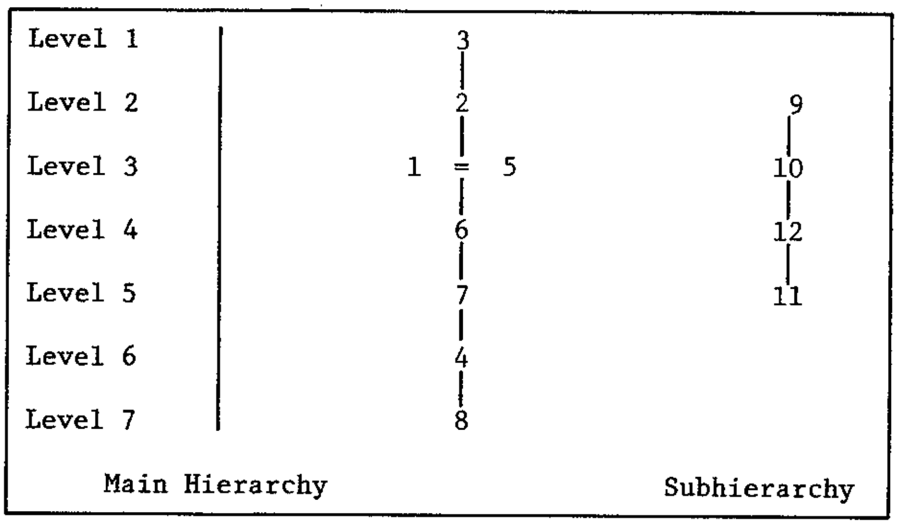


Diagram 5

The splicing process begins by comparing elements 3 and 9. If the statement is found to be true, then the recorder requests elements 2 and 9 to be compared. If this statement is true, then the 9 connects to the 2 as shown in Diagram 6. The splicing process is not complete because the lower end of the 9, 10, 12, 11 subhierarchy may be connected to the main string.

The recorder would then request comparisons of 11 and 8; 11 and 4;

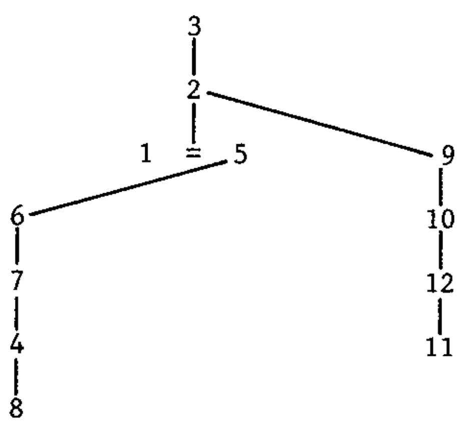


Diagram 6

11 and 7; and 11 and 6 to be made. If no linking is possible at the lower end, the final directed graph is as shown in Diagram 6. It is probably more economical to begin the comparisons of 11 and 6 first and move down the chain until a linking is achieved. If a linking between 11 and 6 is achieved, then the remaining tests with elements 7, 4, and 8 need not be carried out because the results can be inferred.

Revision

When a hierarchy has been completed, the facilitator draws the results on an OHP and presents it to the working group for them to reflect upon. It is relatively easy to modify the hierarchy at this point while considering the structure as a whole.

Building on These Resource Conditions:	Developed by these Procedures:	Tree removal	Ground Cover and/or top soil removal	Excavation/slope cutting	Sand/gravel removal	Land draining	Land filling	Surface compaction	Soil compaction and construction of impervious surface	Stream channelization	Lawns/landscaping	Septic tanks/leaching fields	Fertilizers organic chemicals	Solid waste disposal to land (sanitary landfilling)	Impoundments
Steep slopes		4, 10	1, 12	1, 22	1	4, 19	19, 22	11	22, 4		4			19, 22	8, 16
Shallow soils		1	1	1		10	1	4	4	9	4	20	20	20	8
Soils with low permeability		1	5	5		15	9, 19	5			5	20		1, 13	8, 11
High water tables		4	11	9	9	9	22	22	5	9	5	20	20	13, 20	8
Wetlands		11	4		15	9, 15	15, 18	15	15	9, 16	11, 15	17, 20	17	15, 20	15
Aquifer recharge areas		1	4	11	20	9	11	11	11	11	20	20	20	20	8
Flood plains		1	1, 12	2	2	21	21	11	11	21	4	13, 20	13, 17	13	3, 15
Shore lands		1	1, 16	1	1, 2		14, 15	22	22		4	13, 17	13, 17	13	

Figure 1. Primary Impact Matrix

CNYRPDB

Primary Hazardous Impacts	Secondary Hazardous Impacts	Erosion of slope, bank or streambed increased 1	Stream turbidity increased 2	Sedimentation increased 3	Surface runoff increased 4	Ponding increased 5	Volume and rate of stream flow increased 6	Volume and rate of stream flow decreased 7	Water table raised and ground water supply increased 8	Water table lowered and ground water supply decreased 9	Land vegetation reduced 10	Infiltration reduced 11	Loss of soil nutrients 12	Pollution of surface waters 13	Fish habitat decreased 14	Water fowl habitat decreased 15	Wildlife habitat decreased 16	Aquatic plant growth increased 17	Aquatic plant growth decreased 18	Interruption of surface or subsurface drainage 19	Ground water contamination 20	Shoreline and riverbank overflow increased 21	Increased chance of landslippage 22
Erosion of slope, bank or streambed increased	1		■	2	11		4	/3		11	■	4	■	2, 12	3, 18	18	10	3, 12	2	3		3	6
Stream turbidity increased	2			■					3					■	3, /18	3			■			3	
Sedimentation increased	3								■						■	18			■	■		■	
Surface runoff increased	4	■	1	2		11	■		3	11	1	10	1	1	1	1	1	12	/3	1		■	/5
Ponding increased	5																						■
Volume and rate of stream flow increased	6	■	1	1					■	/1			1, 12	/1	1							■	
Volume and rate of stream flow decreased	7			■						■				■	■	■	■						
Water table raised and ground water supply increased	8	/6				11	■					■								5	■	6	/5
Water table lowered and ground water supply decreased	9			■				■		■					/7	7, 10	/10						
Land vegetation reduced	10	■	1	1	■		4			11		4	4	4	/1	■	■	1, 12	/3	1		4	
Infiltration reduced	11	4	1	4	■	■	4			■	/9		4	4	/1	/1	/1	1, 12	/3	■		4	
Loss of soil nutrients	12		1								■			1	3		10	■					
Pollution of surface waters	13														■	■		12	2		■		
Fish habitat decreased	14															■							
Water fowl habitat decreased	15														■							■	
Wildlife habitat decreased	16	10	1	1	10		4			/11			/1	/1	/3	/10			/2				
Aquatic plant growth increased	17													■									
Aquatic plant growth decreased	18		/1												■	■							
Interruption of surface or subsurface drainage	19	4	1	1	11	■	4	5	/5	11	1	4	1	1	7		/1	/1					
Ground water contamination	20													■	13	13	/13	/13					
Shoreline and riverbank overflow increased	21	■	1	■		■							1	■									
Increased chance of landslippage	22	■	1	/1	/11									/1	/1		/10						

■ Major Direct Impact

☐ Minor Direct Impact

7 Minor Indirect Impact

/3 Minor Indirect Impact

Figure 2. Secondary Impact Matrix

CYNRPDB

Capability Classes	Environmental Education	Wildlife	Erosion Control	Flood Control	Water Supply Protection	Outdoor Recreation	Timber Production	Mineral Extraction	Agriculture	Low Density Residential	Urban Uses
	Potential Uses										
1. Unique Natural Areas	A	B	B	B	B	C	D	D	D	D	D
2. Wildlife Habitats	B	A	B	B	B	C	C	C	C	D	D
3. Erosion Control Areas	B	B	A	B	B	C	C	C	C	D	D
4. Floodland Management Areas	B	B	B	A	B	B	B	B	B	D	D
5. Ground Water Protection Zone	B	B	B	B	A	B	B	C	C	C	D
6. Forest Lands	B	B	B	B	B	A	A	C	D	C	D
7. Mineral Resource Areas	B	C	B	B	B	B	B	A	C	D	D
8. Outdoor Recreation Areas	B	C	B	B	B	A	C	D	D	D	D
9. Prime Agricultural Lands	B	C	C	C	C	D	C	C	A	C	D
10. Low Density Shoreline Residential Areas	C	D	C	C	C	B	C	D	D	A	D
11. Other Non-intensive Use Areas	B	B	B	B	B	B	B	B	B	C	D
12. Existing Urbanization	C	D	C	C	C	C	D	D	D	B	A
13. Remaining Areas	B	B	B	B	B	B	B	B	B	B	B

* A = Best use(s) of area; B = Other compatible uses; C = Potential uses, if precautions taken; and D = Inappropriate or incompatible uses.

Figure 3. Land Use Capability Ranking

CNYRPDB

REVIEW OF HYDROLOGY WATER QUALITY IMPACTS	Changes in Hydraulic Parameters	IMPACTS ATTRIBUTABLE TO: Changes in Watershed Land Use	Construction and Maintenance
Sources of Impacts	-Channel straightening -Levees and channel confinement -Alteration of channel cross-section -Clearing and snagging -Channel lining and protection -Related water resoure development	-Changes in land cover and effects on hydrology -Runoff- and land use-related pollution -Effects on downstream flood hazards -Potential effects on groundwater quality	-Equipment types and construction methods -Sediment-generating activities -Other pollutants and sources -Alteration of groundwater discharge/recharge -Conditions favoring minimal effects on groundwater -Influent versus effluent conditions -Effects of land drainage
Review of Quantification	-General data requirements for impact quantification -Approaches to estimation of downstream hydrologic effects -Hydrologic effects on waste assimilation -Evaluation of channel erosion and sedimentation potential -Influence of substrate on purification capacity	-Evaluation of runoff/ water quality/land use interactions	-Evaluation of thermal regime changes from bank clearing -Relevance of project scale, soils, topography, climate, & vegetative cover variables -Evaluation of pollution from major construction activities -Methods and considerations for groundwater impact quantification
Evaluation of Impacts		-Basis for assessment: water quality criteria and standards	
	-Assessment of assimilative capacity changes and downstream effects -Measures to mitigate adverse hydraulic and water quality impacts	-Assessment of land use impacts related to channelization -Assessment of potential pollution from land use activities	-Purposes of assessing construction and maintenance impacts -Reduction of erosion and sedimentation -Nature and schedules for maintenance -Disposal of excavated material -Protection of groundwater

Table 1. Hydrology and Water Quality Impacts

CURRAN

REVIEW OF AQUATIC ECOLOGY IMPACTS	IMPACTS ATTRIBUTABLE TO: Habitat Alteration by Riparian Vegetation Removal	Habitat Alteration by Channel Excavation and Maintenance	Habitat Alteration by Change in Land Use & Water Quality
Sources of Impacts		-Basic ecological principles underlying impact identification	
	-Effects of instream debris removal -Effects of riparian vegetation removal on temperature, eorsion potential, and habitat diversity	-Turbidity and sedimentation impacts -Reduction of available aquatic habitat -Relationship of velocity to habitat diversity -Effects of groundwater changes and drainage on aquatic ecology -Ecological effects of channel maintenance	-Land use changes due to flood protection or drainage functions -Changes in nutrient, sediment, pesticide, and other pollutant loads; ecological implications
Review of Impact Quantification	-Basic data requirements for characterizing aquatic habitat -Ecological effects of altered temperature patterns	-Quantification of habitat gains and losses -Relevance and need for fisheries, benthic invertebrate, and aquatic plant data -Approaches to evaluation of suspended solids and sedimentation -Tolerance of benthic organisms to pollution -Consideration of impacts on fish spawning and anadromous species migration -Approaches to evaluation of ecological impacts of hydrologic modifications and creation of backwaters (due to channel realignment)	-Baseline data requirements for impact prediction (water quality, land use, etc.) -Uncertainties in impact quantification -Possible shifts of species abundance
Evaluation of Impacts	-Applicability of criteria to ecological impact assessment -Judgment of adequacy of EIS with respect to ecological impact evaluation -Assessment of thermal regime changes -Assessment of suspended solids and sedimentation impacts -Assessment of habitat changes for which no explicit criteria exist -Applicability of mitigation measures		

Table 2. Aquatic Ecology Impacts

CURRAN

REVIEW OF TERRESTRIAL ECOLOGY IMPACTS	IMPACTS ON: Riparian Habitat and Land Use	Wetland Habitat and Land Use	Upland Habitat and Land Use
Sources of Impacts	-Streambank clearing; terrestrial and aquatic ecology considerations -Effects of groundwater changes -Effects of major construction activity on terrestrial ecosystem -Possible indirect effects on riparian habitat and land use	-Wetland drainage and alteration of inundation patterns -Impacts on bottomland hardwoods -Impacts of spoil disposal -Impacts of drainage facilities tributary to main channel	-Impacts of ancillary structures and land treatment (upstream impoundments, cropping practices, etc. -Regional considerations beyond project area

	IMPACTS DEPENDENT ON: Project Dimensions	Land Use and Ecological Value
Review of Impact Quantification	-Basic data requirements for impact estimation (project dimensions, environmental settings, land use inventory etc.) -Approaches to classifying wetlands -Approaches to evaluating importance of wetlands -Evaluation of impacts on urban and recreational lands; aesthetic considerations	-Adequacy of time frame for evaluating land use changes and impact -Categorization of land uses -Economic, social and ecological criteria relevant to land use and terrestrial habitat

Evaluation of Impacts	-General approach for terrestrial impact assessment -Assessment of wetland riparian impacts and interrelationships with aquatic ecological effects -Regenerative potential of impacted areas; rare and endangered species -Assessment of land use impacts -Applicability and assessment of mitigative measures and alternatives

Table 3. Terrestrial Ecology Impacts

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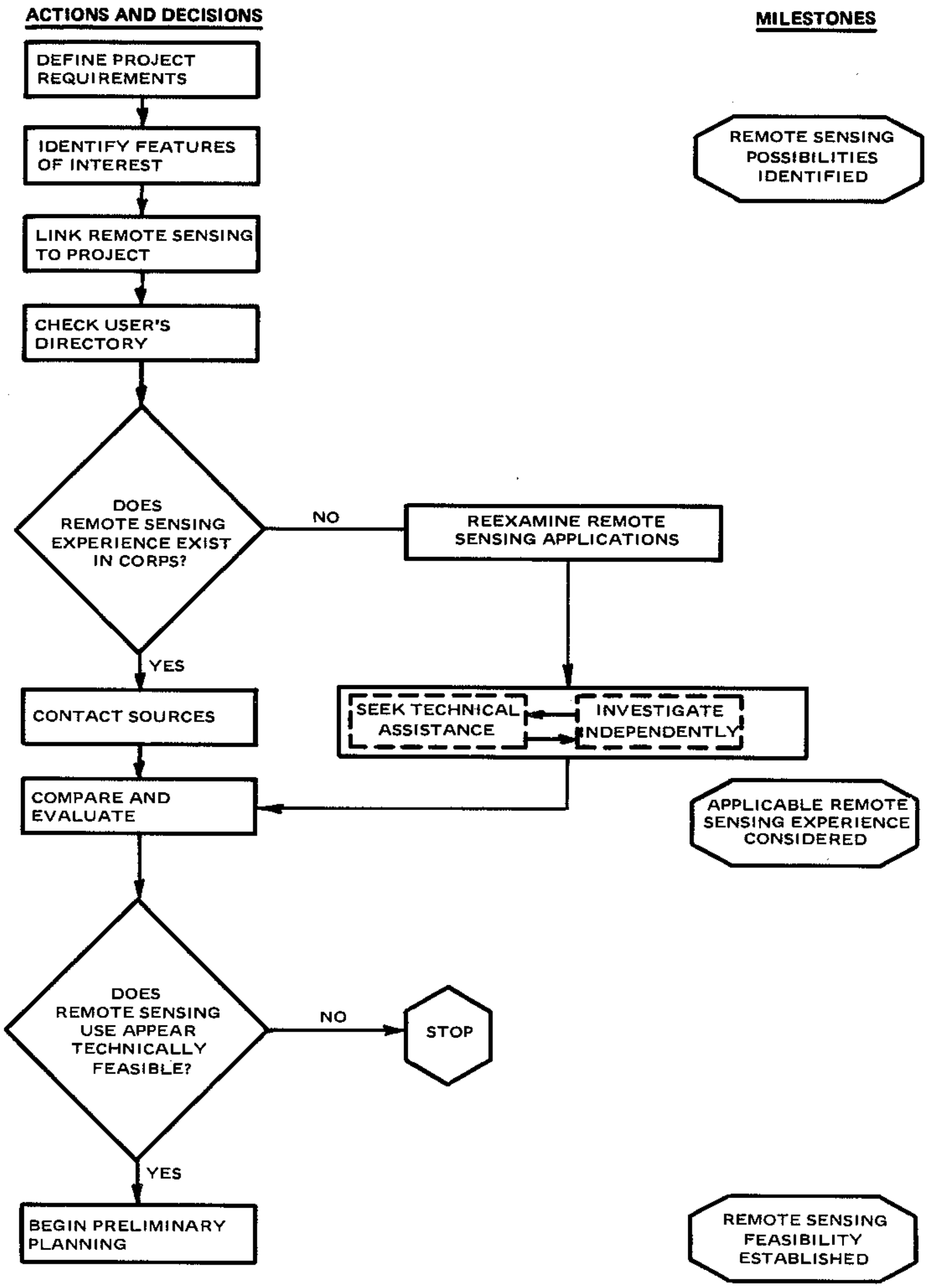

Figure 1. Determining the Technical Feasibility of Applying Remote Sensing.

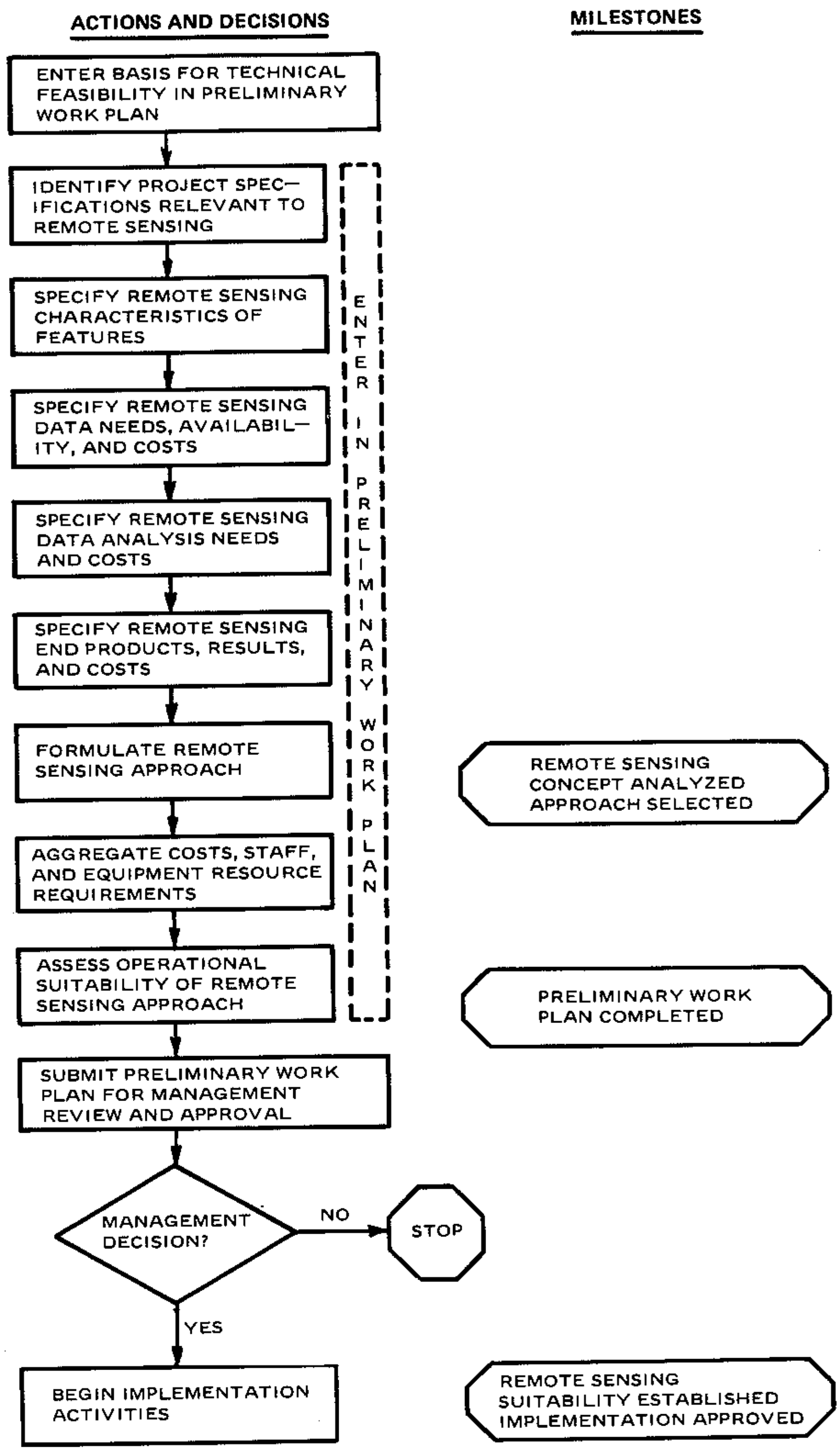

Figure 2. Preliminary Planning for Applying Remote Sensing

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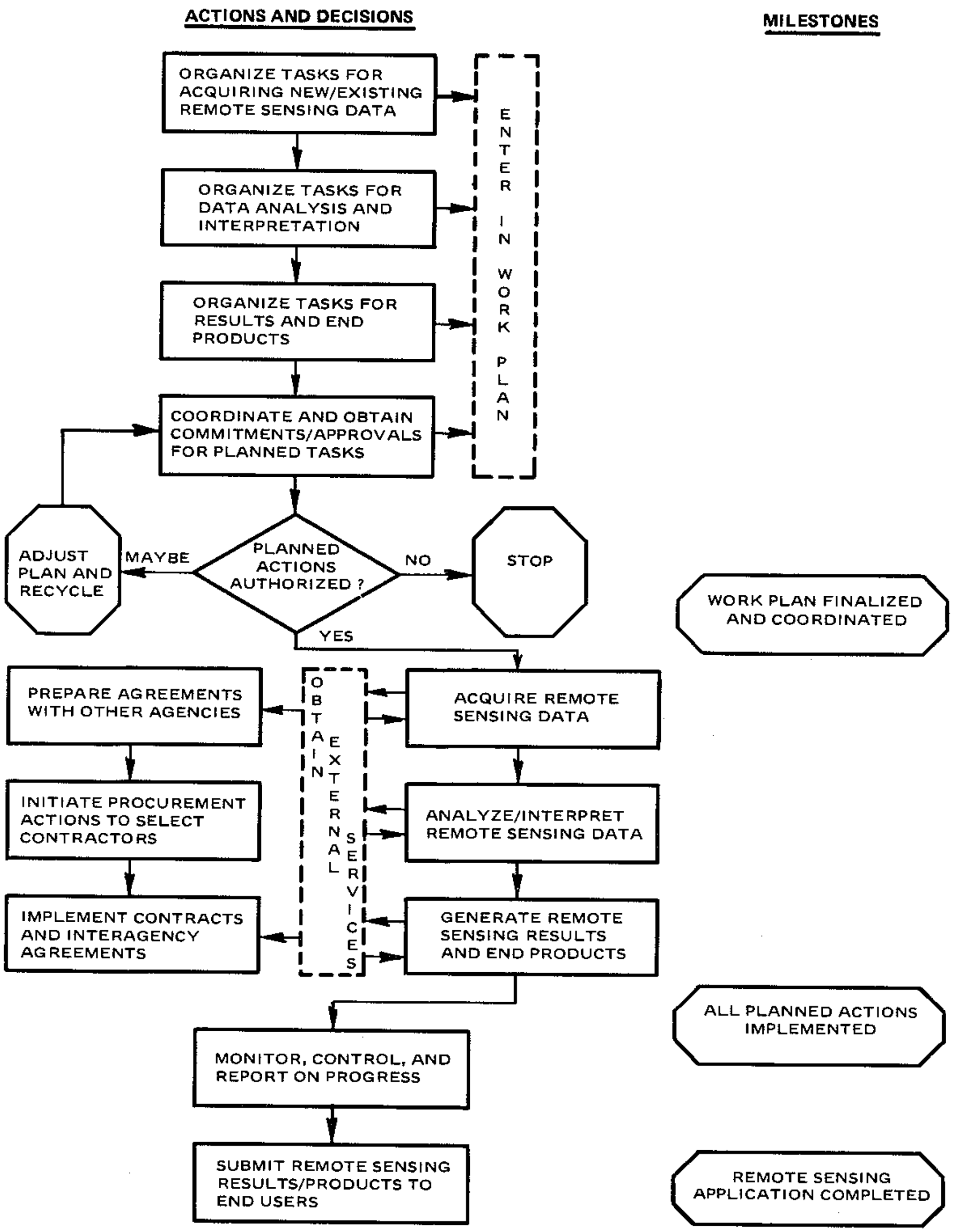

Figure 3. Implementing the Remote Sensing Plan

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Note 1. Environmental Attribute Descriptions

PHOTOCHEMICAL OXIDANTS

Definition of the Attribute. Products of atmospheric reactions between hydrocarbons and nitrogen oxides which are initiated by sunlight are called photochemical oxidants. The product of these reactions which is most commonly found and measured in the atmosphere is ozone. Other oxidants of interest include peroxyacetyl nitrate (PAN) and acrolein. Atmospheric measurement techniques measure the net oxidizing properties of atmospheric pollutants and report these photochemical oxidant concentrations as equivalent ozone concentration. Photochemical oxidants can be found anywhere where hydrocarbons and nitrogen oxides interact in the presence of sunlight.

Activities that Affect the Attribute. All activities that generate oxides of nitrogen and hydrocarbons simultaneously contribute to the generation of photochemical oxidants. Industrial activities and the operation and maintenance of motor vehicles and stationary combustion sources are major sources of nitrogen oxides and hydrocarbons. In addition, many other activities have petroleum and petrochemical operations that emit high levels of hydrocarbons.

Source of Effects. The data from animal and human studies are sparse and inadequate for determining the toxicological potential of photochemical oxidants. Injury to vegetation is one of the earliest manifestations of photochemical air pollution. The oxidants can cause both acute and chronic injury to leaves. Leaf injury has occurred in certain sensitive species after a 4-hr exposure to 100 g/m^3 (0.05 ppm) total oxidants. Photochemical oxidants are known to attack certain materials. Polymers and rubber are important materials that are sensitive to photochemical oxidants.

Variables to be Measured. The variable measuring the extent of photochemical oxidants is the maximum 3-hr concentration (6:00-9:00 a.m.) not to be exceeded more than once a year. The photochemical oxidant level is reported in micrograms/cubic meter.

How Variables are Measured. Since ozone is the major constituent contributing to photochemical oxidants, it is used as the reference substance in reporting levels of photochemical oxidants.

Ambient air and ethylene are delivered simultaneously to a mixing zone where the ozone in the air reacts with the ethylene to emit light which is detected by a photomultiplier cell. The resulting photocurrent is amplified and displayed on a recorder. The range of most instruments is from 0.005 ppm to greater than 1 ppm of ozone. The sensitivity is 0.005 ppm of ozone.

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Data sources. The sources of data are generally the State Pollution Control Department, the County Air Pollution Control Office, or the City Air Pollution Control Office. They can also install monitoring equipment at critical locations near its operations to determine the level of photochemical oxidants generated by its activities.

Skills required. A basic paraprofessional training in mechanical or chemical engineering with special training in operating the air quality instruments is adequate to collect data relating to photochemical oxidants. Specialized supervision will be needed to insure that the data are properly collected and analyzed. Specialized supervision should include trained and experienced personnel or experienced consultants in the field of air quality monitoring.

Instruments. Instruments for carrying out the photochemical oxidant measurement include:

A detector cell

An air flowmeter capable of controlling air flows between 0-1.5 ℓ/min

An ethylene flowmeter capable of controlling ethylene flows between 0-50 ml/min

An air inlet filter capable of removing all particles greater than 5 μ in diameter.

A photomultiplier tube

A high-voltage power supply (2000 volts)

A direct-current amplifier and a recorder

Evaulation and Interpretation of Data. Photochemical oxidants are keyed to the 6:00-9:00 a.m. concentration values. At low concentrations, photochemical oxidants do not pose a problem. The quality of the environment, however, rapidly deteriorates as conditions for smog development approach, i.e., hydrocarbon concentrations of 0.15-0.25 ppm. The values of the oxidant levels during the early morning determine the intensity of the oxidants to be expected later in the day. After sunset, the oxidant concentrations are reduced to low levels.

Geographical and Temporal Limitations. The concentration of photochemical oxidants does not remain constant over the entire spatial extent in a given region. Also, it will not remain constant over time. As such, a substantial spatial and temporal variation in the concentration of photochemical oxidants can be expected. It is generally claimed that the impact of photochemical oxidants in the environment and man depends on the total amount of exposure during the peak periods. The spatial variations can be accounted for by taking small units of urbanized regions for purposes of analysis. This would require extensive calculations based on a diffusion model or a large-scale monitoring program. Since the use of a large-scale monitoring network is infeasible in most situations, the problem can be adequately addressed using diffusion models to predict the air quality values over the entire spatial area.

Mitigation of Impact. All strategies for mitigating hydrocarbons and oxides of nitrogen are applicable to photochemical oxidants.

Secondary Effects. Sensitivity of plants to photochemical oxidants results in economic loss, as well as other secondary impacts on ecological balance. Other economic loss occurs with material deterioration and reduced property values.

Additional References. "Guidelines for Development of a Quality Assurance Program. Reference Method for the Measurement of Photochemical Oxidant," Environmental Protection Agency, August 1973.

BIOCHEMICAL OXYGEN DEMAND (BOD)

Definition of the Attribute. BOD of water is an indirect measure of the amount of biologically degradable organic material present. It is, thus, an indication of the amount of dissolved oxygen (DO) that will be depleted from water during the natural biological assimilation of organic pollutants. The BOD test is widely used to determine the pollutional strength of sewage and industrial wastes in terms of oxygen that would be required if these wastes were discharged into natural waters in which aerobic conditons exist. The test is one of the most important in stream pollution-control activities. By its use, it is possible to determine the degree of pollution in natural waters at any time. This test is also of prime importance in regulatory work and in studies designed to evaluate purification capacity of receiving bodies of water.

Activities that Affect the Attribute. Activities associated with normal operations, maintenance, and repair may contribute to BOD wastes. These human activities, e.g., sanitary sewage, wastewaters from hospitals, food-handling establishments, laundry facilities, and floor washing from shops constitute BOD wastes. If all wastes are collected by a network of sewers to a central location, adequate treatment must be provided to minimize impact upon the surface-water system. If cesspools, septic tanks, and soakpits are utilized, groundwater in the vicinity may become adversely affected.

Source of Effects. The discharge of wastes containing organic material imposes oxygen demand in the natural body of water and reduces the DO level. If wastewaters are treated, the combined sewer overflows and surface runoffs may also exert effects under wet weather conditions. All parameters directly or indirectly related to DO also affect the organic waste assimilation. These parameters include depth of water, velocity of flow, temperature, and wind velocity.

Variables to be Measured; How Variables are Measured. BOD values are generally expressed as the amount of oxygen consumed (mg/ℓ) by organisms during a 5-day period at 20°C. Several other parameters, such as Chemical Oxygen Demand (COD) and Total Organic Carbon (TOC), are also used to represent the organic matter in water and wastewater. COD value indicates the total amount of oxidizable material present and includes BOD. TOC is a measure of bound carbon. Both these tests are closely related to BOD and are used in water and wastewater monitoring programs.

Routine BOD measurements are made in laboratories by dilution techniques; results are obtained in 5 days. Some modifications of BOD tests may require less time. COD and TOC measurements take only a few hours. Several types of instruments are commercially available which measure TOC more or less on a continuous basis.

Evaulation and Interpretation of Data. Since BOD is a measurement of organic pollutant levels of a water body, the lower the BOD level, the better the water quality. The ability of water to assimilate wastes is partly dependent on physical characteristics of the water body. Thus a sluggish stream, reservoir, or lake may show undesirable conditions at BOD of 5 mg/ℓ, whereas a swift mountain stream may easily handle 50 mg/ℓ of BOD without significant deleterious effects.

Mitigation of Impacts. All wastes containing organic wastes should be processed by treatment methods. The treatment methods may include biolocial or chemical processes. Also, several types of packaged treatment units are commercially available that can be installed for desired applications.

Secondary Effects. By virtue of the biological and aesthetic effects of BOD on aquatic environments, secondary impacts are manifested in terms of additional impacts on aesthetics, reduced recreational benefits, and costs to alleviate the direct consequences of BOD on waters scheduled for reuse. The success of land use planning efforts in areas where water is an integral part of the planning effort (e.g., recreational areas or industrial sitings) is dependent upon the quality of those waters. BOD is a parameter of utmost importance.

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EQEP TECHNIQUES SECTION

This section contains measurement and evaluation techniques for use in the Environmental Quality Evaluation Procedures. The technique profiles included here describe methods, techniques, and procedures for characterizing the three attributes, Ecological, Cultural, and Aesthetic, set out in the EQEP rule.

The indicators measured and other information about the techniques are summarized in the Profile Characteristics Matrices or tables.

Techniques addressing the Ecological and Aesthetic Attributes are summarized in Tables B-5 through B-8. For the Ecological Attribute, techniques are included for terrestrial, aquatic, and ecosystem level evaluation.

Due to the nature of cultural resource evaluation, procedures to address the Cultural Attribute were considered differently from the other two attributes. Rather than a number of techniques to measure cultural resources indicators, an outline of procedures to evaluate cultural resources was developed. Profiles explaining the procedures in detail were then developed. The analysis and evaluation resulting from implementing the procedures provides the data on cultural resources and their significance required for the EQEP analysis. The outline is included following the Profile Characteristic Matrices.

TABLE OF PROFILES - EQEP TECHNIQUES

Table B5

Techniques-Terrestrial

Technique Name	Indicator	Basis of Indicator	Units	Comments	Uses	Page
Asherin	Habitat quality	Measurement of habitat diversity	Species population projections	Used computer manipulated data analysis projections	Avian species predictions	B173
Fish and Wildlife Service-Habitat Evaluation Procedures (HEP)	Habitat suitability	Habitat suitability indexes and area	Habitat unit values	Habitat quality for species	Nationwide	B249
Fish and Wildlife Service-Habitat Suitability Models	Habitat Suitability Index (HSI)	Document development of habitat suitability models for fish and wildlife species	0.0-1.0	Models developed for use in HEP or other habitat assessments	Nationwide	B253
Hamor	Habitat quality	Professional judgment on quality of habitat on 0-1.0 scale combined with acreages or stream miles	0.0- ; acre-value or mile-value	Formalized expert judgment method for evaluating overall habitat quality for a species or guild		B210
Hayes	Various terrestrial parameters (primarily vegetative)	Field measurement of parameters	Parameter units			B212
Headquarters, DA Biological Indices draft EP	Brillouin's Index	Species diversity index	0-1.0	Used when every individual is identified, i.e., the sample is the universe under consideration, a finite community	Uses documented in EP	B214
	Shannon-Weaver Index	Species diversity index	Log units	Used with a sample of an infinite community		
	Simpson's Index	Species diversity index	0-1.0	Used with a sample of an infinite community		

Table B5 (Continued)

Technique Name	Indicator	Basis of Indicator	Units	Comments	Uses	Page
Headquarters, DA Bio-indices EP (Contd)	Evenness Index	(1) Distribution of individuals among the species present, (2) defined as ratio of observed to maximum possible species diversity, using Shannon or other index	Ratio	Evenness indexes defined for finite and infinite communities		
	Equitability Index	Evenness based on MacArthur broken stick model				
Herin	Habitat quality	Expert judgment	Quality rating	Relies heavily on remote sensing data and expert judgment	Kansas Dept. of Transportation	B220
Hulbert	Species richness	Expected number of species in a sampled population	Number of species	Standardized sample size used to (1) estimate species richness (2) compare species richness between samples of different sizes		B222
	Proportion of interspecific encounters (PIE)	Information theory type measures i.e., competition and interspecific encounters	0.0-1.0, ratio			
Ott 1979	Air quality	Indexes	0-		Each index user noted	B232
SCS 1977	Habitat diversity	Measurement of (1) habitat interspersion, (2) acreage, and (3) quality of habitat	0-4; wildlife habitat acre value	Aerial photography used	Illinois; adaptable to other regions	B237

Table B5 (Continued)

Technique Name	Indicator	Basis of Indicator	Units	Comments	Uses	Page
Thomas, "Wildlife Habitats in Managed Forests"	Sucessional stage	(1) Identification of successional stages, and (2) species associated with each stage	Successional stage	(1) Relationship of succes-ional tages to reproductive and feeding requirements of species (2) assists in determining impacts to species from alterations in succession, e.g., clear-cutting of forests	Pacific Northwest	B242
USAE Lower Mississippi Valley Division, HES 1980	Habitat quality	Measurement of habitat variables and acreage	0-1.0; habitat unit value	Adaptable to other regions. Habitat quality for habitat types, not species	Lower Mississippi Valley	B244
Whitaker and McCuen	Habitat quality	(1) Model of habitat suitability for two groups of wildlife and (2) acreage of habitat types	0.0-	(1) Similar to HEP, but fewer data requirements. (2) Relies on local experts for model development.	Maryland watershed of 57,000 acres	B267

Table B6

Techniques-Aquatic

Technique Name	Indicator	Basis of Indicator	Units	Comments	Uses	Page
American Public Health Assn. (Standard Methods)	Water quality parameters (Listed in Extended Profile Section)	Analytical methods measurement of physical and chemical parameters	Measurement specific to each parameter	State-of-the-art measurement methods for water quality parameters	Standard water quality reference	B171
Binns	Habitat value for trout	Habitat Quality Index and Habitat Unit values	0- ; habitat value-dimensionless	(1) Developed specifically for trout streams. Methodology adaptable to other species and regions (2) Uses a regression model to relate habitat variables to fish biomass; model is dependent on availability of biomass and habitat parameter availability	Wyoming Trout	B180
Bovee-Instream Flow Incremental Methodology (IFIM)	a. Weighted Useable Areas (WUA) of physical habitat for specific flow regimes b. minimum required instream flows and recommend flows	Hydraulic simulation models and habitat preferences for target species	Area of available habitat	IFIM can (1) predict the habitat available for target species under specific flow regimes. (2) provide basis for determining recommended flow regime given varying study objectives	Nationwide	B184
Fish and Wildlife Service Habitat Evaluation Procedures (HEP)	Habitat suitability	Habitat suitability indexes and area	Habitat unit value	Habitat quality for species	Nationwide	B249
Fish and Wildlife Service-Habitat Suitability Models	Habitat Suitability Index (HSI)	Development of habitat suitability model	0.0-1.0 HSI units	Models developed for use in HEP or other habitat assessment method	Nationwide	B253

Table B6 (Continued)

Technique Name	Indicator	Basis of Indicator	Units	Comments	Uses	Page
Headquarters, DA Biological Indices draft EP	a. Brillouin's Index	a. Species diversity index	a. 0-1.0	a. Used when every individual is identified, i.e., the sample is the universe under consideration, a finite community	Uses are as documented in EP	B214
	b. Shannon-Weaver Index	b. Species diversity index	b. Log units	b. Used with a sample of an infinite community		
	c. Simpson's Index	c. Species diversity index	c. 0-1.0	c. Used with a sample of an infinite community		
	d. Evenness Index	d. (1) Distribution of individuals among the species present (2) Defined as ratio of observed to maximum possible species diversity using Shannon or other index	d. ratio	d. Evenness indexes defned for finite and and infinite communities		
	e. Equitability Index	e. Evenness based on MacArthur broken stick model				
U. S. Environmental Protection Agency	Water quality parameters (listed in Extended Profile Section)	Analytic methods for measurement of physical and chemical parameters in water samples; emphasis on instrumental methods	Measurement units specific to each parameter	State-of-the-art measurement methods for water quality parameters		B247

Table B6 (Concluded)

Technique Name	Indicator	Basis of Indicator	Units	Comments	Uses	Page
Vannote	Stream continuum concept	Relationship of stream order to (1) ecosystem structure and function (2) river ecosystem stability and (3) energy flow	Stream order	Concept provides framework for baseline assessment and basis for describing stream ecosystem response to disturbance		B260

Table B7

Techniques-Ecosystem Level

Technique Name	Indicator	Basis of Indicator	Units	Comments	Uses	Page
Bayley	Energy flow in system	Energy Benefit/Cost Ration	B/C Ratio of coal equivalents		Comparison of coal transportation alternatives	B177
Odum and Cooley	a. Ecosystem profile analysis	a. Ecosystem level indicators	a. Indicator units	a. (1) Holistic approach to ecosystem functions		B229
	b. Dominance-diversity profiles	b. Census data on sampled community	b. Relationship of abundance to biomass or other measurement	b. In many cases, e.g., pollution, there are characteristic profiles for specific conditions		
Wang	Energy flow	Conversion of all energy flows to coal equivalents	Calories; coal equivalents	(1) Allocates land use on basis of energy maximization (2) environmental sector linked to regional input-output model of agriculture, industry, and urban sector (3) requires considerable energy based data	Lee County, Florida	B264

Table B8

Techniques-Aesthetic

Technique Name	Indicator	Basis of Indicator	Units	Comments	Uses	Page
BLM Visual Resource Contrast Rating (VCR)	Visual Contrast	Assessment of changes in visual elements of (1) form, (2) line, (3) color, and (4) texture	0-30 VCR units	Visual impact based on visual contrast	BLM	B189
BLM Visual Simulation Techniques	Visual Impact	Simulation techniques for visual impact techniques	N/A	Variable complexity/sophistication of visual impact techniques		B192
BLM. "Upland Visual Resource Inventory and Evaluation" Forest Service 1974 SCS 1978	BLM-Visual Resource Management Classes (VRM) FS - Visual Resource classes SCS - Landscape Architecture Priorities	(1) Landscape or visual resource quality, (2) land use, and (3) acceptability or sensitiv ity to change in the landscape	BLM-VRM classes FS-classification of sensitivity levels SCS- 3-9 Priority Rating	Ratings and classification provide decision oriented ratings for management decisions on acceptable levels of visual impact, disturbance, or intrusion		B195
Forest Service 1974	Scenic Variety	Evaluation of baseline landscape quality based on (1) form, (2) line, (3) color, and (4) texture	Qualitative evaluation of landscapes	Dependent on characteristic landscape for comparison with baseline conditions	Pacific Northwest	B208
Leopold	Aesthetic Uniqueness	Uniqueness ratio for site components or factors	0.0-1.0, ratio	Comparisons between alternative sites on basis of uniqueness	Hell's Canyon, Idaho adaptable to other areas	B227
SCS 1978	Visual Resource Quality (VRQ)	Desirability/uniqueness of visual resource based on diversity of visual components	Qualitative rating, i.e., distinctive, average, minimal			B240
Smardon	Visual Impact Severity	Ratings of (1) contrast in color, form, scale, and line; (2) scale dominance, and (3) spatial dominance	Impact severity ratings of severe, strong, moderate, weak, negligible	Detailed guidance on implementation of Visual Contrast Rating System		B234

Cultural Resources - Outline of Reconnaissance and Intensive Surveys

I. Literature Review and Archival Search

A. Interviews (oral)
1. collectors
2. property owners and former owners
3. local historical societies
4. county clerks
5. county tax collectors
6. county or city engineers
7. local government officials

B. Archival (written)
1. National Register of Historic Places
2. National Architectural and Engineering Record
3. maps
4. official land holding records
5. state files
6. journal and diaries

C. Professional Literature
1. national journals
2. regional journals
3. ethnographic materials

II. Synthesis and Overview (National/Regional/Local)

A. Existing data
1. geographically
2. temporally
3. information for research topics

B. Data gaps
1. geographically
2. temporally
3. information for research topics

C. Identify future study needs

III. Field Reconnaissance - Identification and Inventory of Resources

A. Define study area
1. description and graphic area display of project alternatives
2. environmental setting pertinent to past cultural usage (as known)

B. Evaluate field sampling methodology(ies)
   1. geomorphological
   2. special studies (ecological)
   3. cultural, e.g., settlement pattern, special activity, subsistence

C. Select/develop field reconnaissance strategy
   1. constraints, e.g., accessibility, ground cover, overburden, time and money, map and photo coverage
   2. stratification variables/weighting
      a. zonation of planning area
      b. percent coverage requirements
      c. level of existing information
      d. anticipated impacts
      e. resource types and temporal periods
   3. field methods
      a. interviews, research
      b. surface
         (1) controlled surface collection
         (2) non-collection
      c. subsurface
         (1) shovel
         (2) shovel assisted survey
         (3) backhoe
      d. documentation

D. Implement field reconnaissance strategy - limited testing and evaluation against National Register criteria

E. Formulate site location model(s) (structured by area of potential impacts)

IV. Evaluation of Field Results

A. Site densities per sampling unit

B. Range of site types

C. Potential site significance
   1. by individual site
   2. by resource district

D. Potential project impact

E. Comparison of alternatives

V. Recommended Plan from Cultural Resources Point of View

VI. Intensive Survey

A. Update feasibility report data

B. Define project area

C. Evaluate intensive survey methodology(ies)

D. Select and develop site evaluation strategies

E. Implement intensive survey

F. Establish National Register eligibility

G. Reassess impacts, establish mitigation priorities

1. Name:

American Public Health Association. 1976. Standard Methods for the Examination of Water and Wastewater, Fourteenth Edition, Washington, D.C.

2. Description:

This text is the most widely used reference of methods for the assessment of water and wastewater. The reference includes measurement techniques for the determination of physical and chemical characteristics of water and wastewater. After a specific water quality parameter is determined to be of interest or importance, Standard Methods is used to determine the appropriate laboratory technique for measuring the parameter.

For each of the parameters, the following are included:

a. Selection of method--available methods for measuring the parameter are presented. Criteria, constraints, or considerations for choosing one method over another method are also included.

b. Sampling and storage procedures--methods are presented for ensuring accurate results from the analytical methods in the proper sampling, preparation, and storage of the water and wastewater samples.

c. General discussion--extremely brief presentation on the significance of the parameter to the evaluation of water and wastewater quality.

d. Interferences--that is, the conditions which could result in variability of the accuracy of each method.

The parameters contained in Standard Methods are included in the Extended Profile section.

3. Applicability:

Standard Methods provides standard analytical techniques for the measurement of physical and chemical characteristics of water and wastewater. The methods are state-of-the-art methods as recognized by field level water quality experts.

4. Advantages and Disadvantages:

The advantage of using Standard Methods is self evident, i.e., its prominence in the field of water quality has made it the state-of-the-art reference on analytical measurement techniques for water quality. However, the interpretation, appraisal, and/or evaluation of the results of the techniques, i.e., the significance of the results of the methods, are not included in the text. The significance determinations are dependent on legal criteria and professional judgment.

5. Previous Uses:

As stated above, Standard Methods is the most commonly referenced text for analytical techniques for the measurement of water quality parameters.

6. Source/Contact:

1. Name.

Asherin, Duane A., Short, Henry L., and Roelle, James E. 1979. "Regional Evaluation of Wildlife Habitat Quality Using Rapid Assessment Methodologies," in Transactions of Forty-fourth North American Wildlife and Natural Resources Conference, Vol 44, pp 404-424.

2. Description.

This paper describes a method to measure terrestrial habitat quality for regional assessments. The method was developed to be a rapid assessment technique for determining habitat quality for large areas using a minimum of field work. This method was developed to measure habitat quality on a 247,000-acre site in Montana-Wyoming being considered for coal development. The assumption on which this method is based is that habitat quality is a direct function of habitat diversity for the majority of terrestrial vertebrate species. Although the method could be used for all vertebrate species in the field application, the method was applied only to birds due to inadequate data bases for mammals and amphibians. Habitat diversity may be evaluated on a regional basis because habitat characteristics that contribute to the diversity of wildlife habitat can be assessed from aerial photography. A field validation study was carried out to collect bird census data for use in regression analyses.

Color infrared photography was used to delineate vegetative habitat classes. Nine major vegetative classes were identified with a total of forty-two variations of the major class types. The photography was used to map the forty-two types using a minimum mapping unit of 40-acre polygons. Vegetative classes and other habitat characteristics are mapped on mylar and then the maps are digitized. The technique made use of the Map Overlay and Statistical System (MOSS) to take the digitized data and calculate diversity indices for each section (640 acres).

The digitized data were used by the MOSS program to summarize a number of habitat parameters for each section. These parameters are:

a. Number, identity, and area of cover types per section.

b. Number of mapped polygons of each cover type per section.

c. Linear amount and identity of edge segments per section.

d. Proportion of each section occupied by individual cover types.

To correlate the data from the aerial photography with population data, a field validation study was conducted. This study gathered census data on the bird population in randomly sampled sites for each of six habitat diversity classes.

Use of the MOSS statistical package requires the development of a species-habitat use data base for species in the area being assessed. The data base contains feeding and breeding information on the vertebrate species in the area. The data base aggregates the various species into life forms or niches according to habitat use for reproduction and feeding.

The bird census data and the habitat vegetative data are utilized in a regression analysis to determine predictive equations for habitat diversity. The four habitat parameters are used to calculate diversity indices for each section. The diversity indices calculated are:

a. Habitat Cover Type Diversity Index (HCTD). The HCTD was calculated by considering the interspersion of cover types within sections determined from the proportion of the area occupied by the different vegetation types.

b. Habitat Strata Diversity Index (HSD). This index measures the diversity in the vertical or structural profile of the vegetation types present in the section. The index is obtained by combining the nine vegetative classes and determining the presence of the combinations in the section.

c. JUXT-Juxtaposition Index. This index is a measure of quality of habitat edge. The JUXT considered the amount, i.e., length of the edge, in a section and the number of species breeding in the cover type making up the edge.

Other variables calculated from the maps are:

d. EDGE-Miles of edge per square mile.

e. NGCT-Number of Grouped Cover Types.

f. NCT-Number of individual cover types.

Using the field data, Bird Species Diversity (BSD) values were calculated using the Shannon Weaver formula and were based on the proportion of the total birds observed per sample section that belonged to each bird species observed in that section.

The regression analysis used the diversity indices and vegetative variables as independent variables and the bird census data as dependent variables.

The regression analysis yielded the three predictive equations for the dependent variables. The correlation of the diversity indices and the BSD values indicated that BSD values may be predicted using HSD and HCTD. Bird species diversity values are thus related to both the complexity of vertical vegetation structure and the mixture of vegetation type.

The prediction equation for number of bird species included the variables EDGE, JUXT, HCTD, and variables describing the number of grouped cover types, and a grouped cover type diversity indices. The number of life forms equation contained the EDGE, JUXT, and NCT variables.

The BSD equation explained more of the total variability (r = 0.74) than the other two equations. In this study, habitat quality could be equated with habitat diversity because (1) BSD is correlated with the number of bird species observed and (2) the number of bird species observed is correlated with the number of life forms. The number of life forms is indicative of the niche potential for vertebrate species.

From the regression analysis, it appears that resource development within a region will impact wildlife and wildlife habitat the least when the development is confined to large homogeneous areas with little vegetative stratification and relatively low cover type diversity. The regression analysis and field data can be used to map areas in which development should be avoided. A maximum BSD value may be calculated from the equation and then areas with a value less than 60 percent of the maximum are rated as having poor habitat quality while areas with greater than 85 percent of the maximum are considered to have high habitat quality. In this manner, habitat quality maps are prepared to indicate areas with high habitat quality to be avoided in development.

3. <u>Applicability</u>.

The methodology described in this paper outlines a technique to measure habitat diversity. Habitat quality is assumed to be a direct function of habitat diversity. This method relies on remote sensing data, computer manipulation of digitized data, and a relatively complete data base on habitat-wildlife use relationships. However, a minimum of fieldwork is required to assess a regional sized area. The methodology was developed to assess baseline habitat quality. It may be used to forecast changes in habitat quality if changes in vegetation types and other habitat parameters are known. Use of the technique to assess the habitat quality for species other than birds is dependent on (1) adequate data bases relating species abundance to habitat, e.g., vegetative, variables, and (2) an adequate understanding of the relationship of habitat diversity and population characteristics.

4. <u>Advantages and Disadvantages</u>.

The chief advantage of this technique is that it provides a rapid assessment of habitat diversity, i.e. habitat quality, with a minimum of fieldwork on a large area. The chief disadvantage is that the analysis is data and time intensive, requiring extensive data bases, photointerpretation, computer manipulation, and interpretation of the analysis.

5. Previous Uses.

This technique has been used to determine habitat quality in a test site in Montana which is under consideration for coal development. The BSD values predicted by the regression equation varied from .01 to 9 percent of the measured BSD. The technique was criticized by one author because it was only able to address avafauna. In addition the delineation of 42 vegetative types, while discernible from color IR, was found to be of greater specificity than necessary.

6. Source/Contact.

The authors may be reached at Western Energy and Land Use Team, U. S. Fish and Wildlife Service, Fort Collins, Colo.

1. Name:

Bayley, Suzanne et al. 1977. "Energetics and Systems Modeling: A Framework Study for Energy Evaluation of Alternative Transportation Modes," IWR Contract Report 77-10, U. S. Army Engineer Institute for Water Resources, Fort Belvoir, Va.

2. Description:

This report presents the concepts of energetics and describes the use of energetics in the evaluation of alternatives. The term energetics has been ascribed to the concepts of energy, energy flow, and interactions as set out by Dr. Howard T. Odum. Basically, energetics deals with the analysis of the energy of a system, the flow of energy through the system, and changes, both in the form of energy and in the energy flow. This particular report applies concepts of energetics to evaluation of alternative transportation systems.

Introductory sections of the report discuss general energy theory, laws of energetics and methods to analyze energy flow. Utilization of concepts of energetics requires development of a detailed systems diagram which shows how components of a system, aquatic habitat for example, are related. Through the use of the system analysis, the changes in energy caused by a project may be analyzed. Using the energy system diagram, the report sets out methods whereby an energetic benefit/cost ratio may be calculated. The energetic B/C ratio takes into account changes or conversions in the natural energy of a system. All energy units are expressed in terms of Fossil Fuel Coal Equivalents (FFCE).

The energy analysis procedure set out by the report consists of the following steps:

a. Identify the scope of the analysis - Energetics may be utilized to analyze energy changes on different scales, e.g., an ecosystem or a single organism.

b. Identify the boundaries of the system.

c. Model representation - A systems model is developed using Odum's symbols. All system components and energy flows are represented. The model may be used to develop a mathematical model of the system. A differential equation can be written for each of the variables or components.

d. Assign energy values - Energy values are placed on the energy flows and components. The report explains the methodology used to assign energy values in the system. Energy values are presented in terms of FFCE so that other forms of energy, e.g. electricity, sunlight, or steam must be converted to FFCE.

e. Analysis - Two types of analysis may be accomplished using the energetics model:

(1) Static Analysis - This consists of calculating energy flows.

(2) Dynamic Analysis - This involves mathematical simulation in order to observe the behavior of the system through time. This type of analysis requires use of first order differential equations. The object of the dynamic analysis is to see how the mathematical model of the system responds to changes in the flows making up the system.

3. Applicability:

An energetics analysis is a type of systems analysis focusing on the energy relationships of the components of the system. Energetics could be used to analyze the impacts of alternatives for Corps projects. Quantifying all energy flows within a system is so complex that implementing a full energetics analysis may be prohibitive in terms of required resources. However, the ability to identify energy inputs, outputs, feedback mechanisms, and interactions enables the planner to have a framework in which to trace impacts in terms of energy.

An energetics analysis may be used in the Evaluation of Effects step to identify and trace potential energy impacts. It is likely that due to data and resource requirements, quantification to measure impacts may be limited.

4. Advantages and Disadvantages:

Energetics provides a method for accounting for energy impacts caused by projects. Its use is limited by its requirements for definitive quantitative data on specific energy impacts.

5. Previous Uses:

This report documents the use of energetics to develop energetic benefit/cost ratios to compare alternatives for coal transportation systems.

Energetics has been used to model energy flows in estuaries and coastal ecosystems (see Odum et al. in Source/Contact).

6. Source/Contact:

See also: Meyers, Caldwell D. 1977. "Energetics: Systems Analysis with Application to Water Resources Planning and Decision Making," IWR Contract Report 77-6, U. S. Army Engineer Institute for Water Resources, Fort Belvoir, Va. This summary report describes the historic development of concepts of energetics and evaluates

their use for application in water resource planning and decision-making.

Odum, Howard T. et al. 1977. "Energy Analysis and the Coupling of Man and Estuaries," Environmental Management, Vol 1, No. 4, pp 297-315.

1. Name:

Binns, N. Allen. 1978. "Evaluation of Habitat Quality in Wyoming Trout Streams," in Proceedings of a Symposium on Classification, Inventory, and Analysis of Fish and Wildlife Habitat. FWS/OBS-78/76, Office of Biological Services, Fish and Wildlife Service, Washington, D.C.

2. Description:

This paper describes a method to evaluate fish habitat utilizing habitat parameters to develop a regression model for desirable habitat. The model relates the habitat variables to biomass of fish production. The model, called the Habitat Quality Index (HQI), is a predictive model which is used to evaluate trout habitat. Using the HQI scores and trout production measurements, a so-called Habitat Unit (HU) is determined. The HU is defined as the amount of habitat quality required to produce an increase of one unit of trout biomass.

The development of the HQI model was based on relating a number of parameters which were thought to contribute to or determine habitat quality. It is assumed that the higher the habitat quality, the higher the observed trout biomass. Among the original twenty-one parameters correlated with biomass were included such things as stream width, fish food abundance, and maximum summer stream temperature. The parameters showing the highest correlation were

a. Critical period streamflows.

b. Annual stream flow variation.

c. Maximum summer stream temperature.

d. Water velocity.

e. Cover.

f. Stream width.

g. Food abundance.

h. Food diversity.

i. Nitrates.

j. Streambank stability.

The model developed took the form

$$HQI = \log (Y + 1.0) = (-1.18257) + (0.97329) \log(1.0 + X_1)$$
$$+ (1.65824) \log (1.0+X_2)$$
$$+ (1.44821) \log (1.0 + X_3)$$
$$(0.30762) \log (1.0 + P)$$

where

Y = standing crop of trout

X_1 = critical period streamflow

X_2 = annual streamflow variation

X_3 = maximum summer stream temperature

P = the product of the last seven parameters, d-j.

For a number of test streams, the HQI was calculated and correlated with trout biomass for the stream. This resulted in a 95 percent correlation. The HQI model thus showed a close relationship with biomass and the HQI model was seen to be a realistic measure of habitat quality for the Wyoming trout streams.

The values for the X_1, X_2, X_3, and P values in the HQI equation are actually ratings assigned according to outlined criteria. For instance the X_3 value is given a rating of 0-4 based on the measured temperature and where the measured temperature falls within the rating criteria. For an evaluation using the HQI model, measurements of the parameters included in the HQI model are converted to the 0-4 ratings.

The HQI model was utilized to determine the Habitat Unit value for trout, i.e., the amount of habitat quality required to produce an increase, in standing trout of 1 lb/acre (1 kg/ha). The HU value may then be used to estimate the biomass that could be expected from a trout habitat. The value of one trout Habitat Unit is referred to as the Habitat Unit Coefficient, θ_s. The θ_s is the amount of habitat quality as measured by the HQI needed to produce an increase in trout standing crop of 1 lb/acre (1 kg/ha).

The HU was calculated utilizing a regression equation relating biomass to the HQI score. This equation takes the form $Y = 12.2 + 0.84(X)$, X being the Habitat Unit value. By using successive values of Y, a unit value for X may be determined. The θ_s for this study was 1.19.

To evaluate a stream for trout habitat requires the relationship

$$H_s = (HQI)X(\theta_s)$$

where

H_s = the Habitat Value of a trout stream

HQI = the Habitat Quality Index score

θ_s = the Habitat Unit Coefficient = 1.19

To calculate the habitat quality of a given trout stream, the HQI value is determined using the model. This value is then multiplied by 1.19 to give the Habitat Value of a trout stream.

The HU values were used to assist in the calculation of HU losses and gains for two proposed reservoirs. Because the trout habitat in the reservoir differs significantly from the stream habitat it replaces, a number of additional concepts were used to evaluate the reservoirs. These concepts were

a. Morphoedaphic Index (MEI) - a fish yield estimator.

b. Ecological Completeness factor - measure of the trout's ability to complete its life cycle in a specific aquatic habitat.

c. Habitat Integrity Factor - measure of the aging of a reservoir, that is, how long can a reservoir be expected to function as a trout producer.

A Habitat Unit Coefficient for reservoirs θ_R was calculated and a previously developed model (cited in the text) was used for calculation of a θ_R. The θ_R was calculated as 0.17 and used to calculate the change in HU for two proposed reservoirs.

3. Applicability:

The method outlined above could be used to calculate the habitat value of a stream for production of trout in terms of trout HU. The habitat value may be used to evaluate a stream's habitat value for the species for which the HQI model was developed. The method, because of its species model approach, would be used when the habitat for a single species or guild were important for consideration.

4. Advantages and Disadvantages:

Use of correlation analysis and regression analysis is required for the development of HQI models and calculation of θ_s. These analyses are dependent on the availability of data on biomass and the habitat parameters. Unless these data are available, the regression H_s and θ_s values cannot be calculated. Because of geographic variability in stream habitat, the HQI models developed may require adjustments for use in other areas.

5. Previous Uses:

This method was developed to determine habitat gains and losses in trout streams in Wyoming. The reservoir evaluation compared habitat losses for two proposed reservoirs using stream habitat values from the HQI models.

6. Source/Contact:

N. Allen Binns, Wyoming Game and Fish Dept., 206 Buena Vista, Lander, Wyo. 82520

1. Name:

Bovee, Ken D. 1981. "A User's Guide to the Instream Flow Incremental Methodology," FWS/OBS-80/52, Instream Flow Information Paper No. 12, Cooperative Instream Flow Service Group, U. S. Fish and Wildlife Service, Western Energy and Land Use Team, Fort Collins, Colo.

2. Description:

This information paper summarizes the Instream Flow Incremental Methodology (IFIM). The IFIM is a set of computer models and analytic procedures designed to predict changes in aquatic habitat due to changes in instream flows. The IFIM may be used to assess the impacts on habitat from such things as a change in channel structure, alteration in waste loading, or implementation of a specific flow regime. As such, the IFIM may be used in Level C planning for instream flow studies, e.g., allocation studies and project impact studies.

The IFIM is based on the determination of microhabitat availability of target species. Determination of habitat availabilities is based on field measurements and hydraulic simulations to calculate the relative amounts of habitat conditions in a channel for a particular discharge. The Physical Habitat Simulation (PHABSIM) program generates the habitat availability values, known as weighted usable area (WUA) for each discharge of concern. PHABSIM utilizes field measurements from field transects to generate WUA. PHABSIM takes each transect used in field measurement and divides it into a number of cells or divisions. PHABSIM uses concepts of open channel hydraulics to predict changes in depth and velocity in each cell as a function of each discharge.

Two hydraulic simulation programs, IFG2 and IFG4, are used with PHABSIM. These programs produce water surface profiles and the output is in the form of a predicted depth and velocity for each stream cell for each discharge to be evaluated for habitat availability. The IFG2 program requires input for only one flow. The IFG4 requires input for three widely spaced discharges.

Each stream cell generated within PHABSIM has a discrete combination of depth, velocity, and substrate and cover. In order to evaluate the utility of that combination of conditions, it is necessary to approximate a function which specifies the preferences or tolerances of the target species for the different combinations of conditions. This is defined as a combined or joint preference function. Four methods for specifying preference functions may be used in the PHABSIM system. The methods are: binary criteria, preference curves, multivariate suitability functions, and multivariate functions in association with performance curves. The method chosen is dependent on data availability and the preferences of target species for various conditions. The Instream Flow Group (IFG) has developed a computer program called GOSTAT which is capable of describing a multivariate suitability function. The chief advantage of this type function is the inclusion of interactions among variables. In addition, the IFG developed preference curves or probability of use criteria for a number of species. Whatever method is used to develop preference functions, the objective of the function is to develop a linkage between flow, i.e., velocity, depth, width, and usage of the microhabitat.

The joint preference functions and PHABSIM form the basis of the IFIM methodology. The determination of instream flow requirements is, however, more complicated than inputting data to the PHABSIM system. Although the IFIM focuses on the usage of microhabitat by target species, the analysis requires characterization of macrohabitat conditions. The macrohabitat analysis requires determination of the status of watershed and stream relationships in terms of sediment loading, channel structure, water quality, and flow regime.

Detailed guidance is presented for the scoping and applying the incremental methodology. The total length of river to be studied is separated into river segments. Each segment is considered to be constituted of a series of reaches with a common morphology, i.e., the same temperature and water quality characteristics, same flow regime, and inhabited by the same species of fish and invertebrates. A sampling plan is developed to determine representative reaches in each segment. These reaches are used to represent the conditions in the entire system.

After scoping and reach selection, description of the system in its present state is required. The description of the present state includes:

a. Channel structure, overall structure and dimensions.

b. Flow regime - median monthly hydrograph; high and low water year hydrographs; present flow conditions; most probable hydrograph and extreme events known or assumed to be deleterious to a fish population.

c. Water quality - primarily temperature and conservative and non-conservative pollutants directly affecting habitat suitability.

After delineation of present conditions, the analytical procedures required to solve the particular study problems are determined. This determination requires examination of problems exhibited and then identifying the procedure required for the problem. For instance, an instream flow study where there are no problems with macrohabitat features will have its main focus on microhabitat versus discharge. Whereas a study where there are some problems with macrohabitat features will focus on both the macro- and microhabitat levels. With the focus determined, an instream flow study is developed for a set of target species. All life stages of each species are considered. Available habitat is determined for each life stage, rather than only the adult stage.

Habitat availability is determined by stream segment. For each segment, the following information is obtained:

a. Streamflow characteristics for segment.

b. Mean monthly flow for segment (50 percent exceeding or 20-year recurrence interval corrected for diversions and return flows).

c. 90 percent exceedance flow for segment.

d. Dominant discharge for segment.

e. Percent of time dominant discharge is equaled or exceeded on daily flow duration curve for months under consideration for channel maintenance.

This information is required for each month. At this point, the length of stream represented by each reach is calculated.

The next step in the analysis is to determine how much of the represented section has adequate water quality for each target species and life stage. Use of temperature models and water quality models for the flows in question in conjunction with temperature and water quality criteria for the target species and life stages enable determination of how many stream miles have suitable water quality and/or temperature. This section length affected by water quality is an important consideration because it is the effective stream length to which the evaluation of habitat conditions may be extrapolated. The usable length of each represented section is determined for individual species and life stages whenever possible. The usable length is determined over a range of discharges, the lowest of which is the 90 percent exceedance flow for the month, and the highest, the 50 percent exceedance flow for the month.

At this point in the analysis, the output from PHABSIM is utilized. PHABSIM provides the weighted usable area values. A WUA value is predicted for each measured reach, each life stage and species, and each flow occurring in the reach. The WUA provides output in square feet per mile of usable habitat. To integrate the WUA values with the water quality segments, the WUA in square feet per mile is multiplied by the miles within the represented section having suitable water quality. The WUA totals for all the represented sections are summed for corresponding life stages and flows to obtain a total usable habitat value for the entire segment.

For each month, the analysis of habitat availability over available range of flows is calculated. For each discharge, minimum WUA values are produced for each life stage. Inspection of this analysis allows the user to determine the WUA for each flow. It is possible to determine the optimum flow for each life stage of the target species.

The minimum WUA value for each discharge represents the WUA required for all life stages of the species. The highest of the minimum WUA values (for all flows) is the WUA value that corresponds to the flow that best maximizes the available habitat for all life stages. Maximization of a particular life stage, e.g. adult, would require identifying the flow that provides the highest WUA for that stage.

The use of the WUA values for recommended flows is dependent on the study objectives. If maximization of a particular life stage is the objective, the recommended flow may be different than if the objective is to obtain a minimum flow for the species.

The recommended flow regime should be constructed which represents either an improvement in the present temporal distribution in habitat or results in no change from present conditions. For this recommendation, the first step is to identify the life stage, flow, and available habitat that is limiting the population under a given flow regime. This requires development of:

a. Mean monthly discharges which could be expected.

b. Annual hydrographs of varying percent exceedances for the stream segment.

c. Weighted usable area values corresponding to a median year flow regime.

Use of these values allows determination of a flow regime which would ensure protection of the limiting flow.

Examination of PHABSIM output reveals the constraining factors in flow regimes. It may be revealed that available food producing habitat, or fish habitat, are constraints to maximum habitat use.

The development of WUA values does not take into account population dynamics. The WUA values produced assume that all life stages need the same amount of habitat. It is possible to consider the habitat requirements in all life stages in the same context, i.e., the adult equivalent habitat area concept (AEHA). The AEHA values are developed by taking into account a number of carrying capacity considerations of the younger life stages and then developing conversion factors for AEHA. The aspects of carrying capacity considered are:

a. Average fecundity of the population.

b. Average nesting or spawning density.

c. Average egg survival.

d. Average annual fry density (per unit WUA) and fry survival.

e. Average annual juvenile density (per unit WUA).

f. Average adult density (per unit WUA).

By using density and survival rates, and WUA from fry and juveniles, a numerical constant is developed for converting WUA for juvenile and fry into AEHA.

AEHA may also be calculated for invertebrates used as food, only instead of densities and survival rates, ratios of annual production are used. The determination of AEHA is considered optional, not a required part of the instream flow analysis.

3. Applicability:

The IFIM can be utilized for determining the available aquatic habitat, the WUA values, associated with different flows. This analysis can be used to predict changes in habitat which result from construction or operation activities which alter the structure of a stream channel or stream flow within the channel. The IFIM can quantify changes in habitat for each target species and life stage caused by changing the flow regime, altering the channel structure, or changing conditions in the watershed. The joint preference functions and the hydrologic simulation models result in identifying minimum flow requirements for each life stage of the target species. The use of IFIM may thus be used to quantify impacts to fish habitat and to form the basis for a recommended flow regime.

4. Advantages and Disadvantages:

The chief advantage of the IFIM method over other fish habitat evaluation systems is in the capabilities provided by the computer simulation models which enable calculation of the WUA values for the different flow regimes. However, use of the computer capabilities is data and time intensive.

5. Previous Uses:

6. Source/Contact:

Cooperative Instream Flow Service Group, Western Energy and Land Use Team, Fish and Wildlife Service, Fort Collins, Colo.

1. Name:

Bureau of Land Management. 1978. "BLM Manual Section 8431-Visual Resource Contrast Rating," Bureau of Land Management, Washington, D.C.

2. Description:

The Visual Resource Contrast Rating (VRCR) technique is a method for measuring the visual impact of proposed activities on a landscape. Visual impact is assessed by determining the degree of contrast that is created between an activity and the existing landscape character. The landscape being assessed is separated into landform, vegetation, and structural components. For each component of the landscape, basic visual elements are described and predictions are made of the degree of contrast resulting from project activities. The degree of contrast an activity has with the landscape is assigned a numerical value.

In application, the system is applied at a specific viewpoint at a site or study area. The basic elements of the landscape to be evaluated are: form, line, color, and texture. Guidance is given for evaluating these four elements for each landscape feature.

The ease of detecting contrast, and thus visual impact, varies with the different elements. Because of this, the values for degree of contrast are multiplied by another value for the element. This is essentially a weighting of the elements.

To determine contrast, each basic element is evaluated on the degree of contrast that will occur with a proposed activity. The values for contrast are multiplied by values for each element and then products are summed for each of the three landscape features. The values used for degree of contrast and weighting are presented below.

Elements	Value	Degree of Contrast	Value
Form	4	Strong/High	3
Line	3	Moderate/Medium	2
Color	2	Weak/Low	1
Texture	1	None	0

Evaluation of contrast rating is to be accomplished taking into consideration the following factors:

a. Distance; the interval between the project and the point from which it is viewed.

b. Angle of observation.

c. Length of time the project is in view.

d. Relative size or scale.

e. Season of the year.

f. How light will affect the project being viewed.

g. Time, the short- and long-term impacts or successional changes may be required.

Evaluations are made for each potential alternative at a site. The alternative evaluations can then be compared to determine the contrast, i.e., visual impact, caused by the activities in a project.

The manual does not explain how project changes are to be visualized for evaluation. A review of visual simulation techniques is contained in the Bureau of Land Management "Visual Simulation Techniques" Profile.

3. Applicability:

This technique is referenced in the Environmental Quality Evaluation Procedures (EQEP) as a method for evaluating visual contrast, that is, the visual impact of a project. The VRCR system can be applied by a CE landscape architect or other planning team member with training in aesthetics. Implementing the system requires site visits and perhaps some photographic supporting services. Other necessary data would be available from the topographic maps and planning documents available toward the end of a planning study.

The results of this technique may be used to compare the visual impacts of different activities at a single site; comparing the impacts at different sites will be difficult, as the technique is not designed for this.

This technique may be used to identify and measure visual impacts in the Evaluation of Effects step. The output from this technique fulfills EQEP requirements for the Forecast With-Plan Conditions, Forecast Without-Plan Conditions Activities, and the activities of the Assess Effects Phase.

4. Advantages and Disadvantages:

The advantages of this technique are that it is systematic and can be easily applied to CE activities. As with most aesthetic and landscape preference techniques, it relies on a degree of subjective judgment when applied in the field, this being a disadvantage. However, the chief disadvantage of utilizing this technique as set out in the BLM Manual Section is that there are few guidelines for application of the VRCR. In addition, subsequent research indicated the weights and basic elements should be changed. See the Smardon profile for these changes. The Smardon reference gives complete guidelines for use of the basic elements to assess visual impacts; however, it has not been widely distributed.

5. Previous Uses:

6. Source/Contact:

   Robert Ross, Bureau of Land Management, Washington, D.C. (202) 343-9353.

1. Name:

Bureau of Land Management. 1978. "Visual Simulation Techniques," Division of Recreation and Cultural Resources, Bureau of Land Management, Washington, D.C.

2. Description:

This report describes visual simulation techniques used to simulate visual impacts. The techniques range in complexity from an illustrator's freehand drawing of a landscape to computer plotting of landscape features. The techniques use a variety of methods to simulate project features on existing landscapes. The specific method used to assess visual impact is dependent on the type of project feature, e.g., vertical cooling towers versus transmission lines, availability of photography, and the availability of detailed project designs. This report summarizes the simulation techniques under three levels of complexity.

a. Manual Techniques

1. Freehand drawing - drawings "from scratch" prepared by an illustrator.

2. Rendering from a projected slide - the major features of a landscape are rendered from a projected slide. An image of the proposed activity is then projected and drawn on the rendering.

3. Diazo print - an illustrator's conception of a proposed activity is applied to a diazo reproduction (mylar acetate or paper print) of a landscape setting.

4. Rendering on a photograph - the major features of an activity are "painted in" a photograph.

5. Etching on a slide - direct alteration of a slide. The photographic emulsion in the area to be simulated is chemically removed or scratched off and the proposed modification painted in with translucent (nonopaque) color medium.

6. Multi-Image Printing - combining color transparencies of several images into a single composite print. Simulating structures on landscapes may be accomplished through making a single color transparency by double printing transparencies of the landscape and the structure.

7. Photomontage - parts of one photograph pasted down upon another photograph. If the proposed modification is a structure and an accurate example can be placed in a setting similar to the proposed site, this is a simple and effective method.

8. Scale-model - three-dimensional simulation of an activity and its setting.

b. Projection Techniques

1. Single overhead - use of a single overhead projection unit to project either a retouched viewgraph transparency or a transparency with simulation overlays.

2. Slide/overhead - a color-slide projection with one or more overhead projectors superimposing an image onto a background setting.

3. Overslide/Overhead - color slides projected through overhead projectors, superimposed into a single image on the screen. This requires a bottom-access overhead projector and an overslide projection cabinet.

4. Slide - projected montage - the images of two or more slides projected simultaneously on a viewing screen.

5. Multi-screen - surrounding an audience with projection screens illuminated by several projectors that collectively show a broad field of view. (Views of up to 360° are possible.)

6. Multi-overhead - this requires use of a sophisticated simulator that uses up to four overhead projectors to superimpose multiple transparencies and overlays into a single image. This simulation technique provides one of the best methods to illustrate realistic color of proposed activities.

c. Computer Techniques

1. Computer perspective montage - this uses a computer program to generate a perspective line drawing of a specific proposed landscape change, such as a road, which is then mounted on a photograph of a setting. An illustrator may then enhance the simulation by painting over the line drawing.

2. Desk-top computer perspective plots - these plots are produced by desk-top computer programs that allow the simple line-drawn perspective depiction of vegetation and land modifications. These programs require that landform data be digitized from topographic maps. The output from these programs are true-scale line drawings. Programs are available for simulating (1) seen areas (plan view), (2) landform (perspective), and (3) existing and proposed vegetation patterns (perspective). The computer programs are available on a rental basis.

3. Applicability:

The techniques summarized in this manual can assist in the determination of visual impact through simulation of the landscape with project features in place. Visual simulation techniques provide a way for visual impacts to be assessed. The techniques provide a basis for applying criteria or parameters for judging visual impacts, such as the basic elements of the Visual Resource Contrast Rating System (see BLM profile). The techniques are a simple method for forecasting With-Plan Conditions.

4. Advantages and Disadvantages:

The Visual Simulation Techniques presented are relatively simple methods to simulate impacts on the landscape. The photographic illustrator services and other required resources are either found within a District or are readily available.

5. Previous Uses:

Each technique summarized in the report has an example of a previous use.

6. Source/Contact:

For each technique, there is a published reference and/or a point of contact, usually within a Federal agency.

1. Name:

Bureau of Land Management 1978. "BLM Manual Section 8411--Upland, Visual Resource Inventory and Evaluation," Bureau of Land Management, Washington, D.C. Forest Service 1974. "National Forest Landscape Management, Vol 2, Ch. 1, The Visual Management System," Washington, D.C. Soil Conservation Service. 1978. "Procedure to Establish Priorities in Landscape Architecture," Technical Release No. 65, Washington, D.C.

2. Description:

The cited techniques are referenced in the Environmental Quality Evaluation Procedures (EQEP) because they provide a method to determine aesthetic (visual) quality. The techniques are considered together because they utilize similar criteria to determine scenic quality and because of the similar purpose of the overall procedure. Subsequent work by Smardon (see Smardon profile) showed that changing some of the criteria used would improve the reliability of the resulting evaluation.

These procedures were developed by the respective agencies to provide an objective treatment of landscape values in planning. The procedures are to be utilized in large planning areas, e.g., basin or subbasin, to inventory the landscape and determine its susceptibility or sensitivity to modification. The measures of sensitivity are used by the agencies to develop guidelines or management objectives. The three procedures determine the susceptibility to modification by considering these factors for a planning area:

a. Landscape or visual resource quality

b. Landscape use

c. Acceptability of change or sensitivity to change in the landscape

The determination of visual or scenic quality is accomplished by describing and rating landscape features in terms of their basic visual elements. The landscape features considered are:

BLM	FS	SCS
Landform	Landform	Landform
Vegetation	Vegetation patterns	Vegetation
Water	Water forms	Water
Cultural modifications	Rock formations	Structures
Adjacent scenery		
Scarcity		

The landscape features are described and rated in terms of basic visual elements.

These elements are:

BLM	FS	SCS
Color	Color	Color
Line	Line	Texture
Form	Form	Vegetation patterns
Texture	Texture	Topographic patterns

The evaluation of landscape features by using the basic elements results in the assigning of visual quality measurements to each area. The resultant quality measure for the procedures are represented as:

	Quality Measure	Explanation
BLM	Scenic quality	Aesthetic quality
FS	Variety class	Distinctiveness of landscape
SCS	Visual resource quality	Uniqueness of landscape

The assignment of quality measure to a particular landscape is based on examining the basic elements of the landscape features and comparing this evaluation to the surrounding landscape. Typical surrounding landscape is used to judge the specific landscape being assessed as being unique, distinctive, or common. The assignment of a quality class or measure for an area allows the classes to be mapped.

The quality classifications determined by the above procedures are combined with other factors to determine management strategies for the use and development of the area in questions. The factors used in addition to the quality measures are:

BLM

Visual Sensitivity Levels based on

a. Judgments on the acceptability of various activities by the public or the planning team and

b. Use volume, that is, the number of persons viewing the modification

SCS

a. Landscape use - based on judgments about importance of the use of the landscape, user volume, and frequency of sight of the landscape.

b. Visibility - judgments based on estimated number of viewers, their probable expectations, and their relative ability to see the landscape from their location.

FS - Sensitivity levels - based on the major and minor concerns expressed by the public about visual quality as viewed from major and minor routes.

The evaluation of these factors to determine the management strategies for the areas, as stated above, rely on public input or judgments about acceptability of modifications to the landscape.

The output of combining the visual quality measure with the above factors results in the following management determinations:

BLM - designation of Visual Resource Management (VRM) classes. Each class has definite limits on the degree of acceptable modification allowed to the landscape.

FS - determination of visual resource management objectives for an area. These planning objectives or goals delineate acceptable modifications or activities such as Preservation, Retention (of present visual quality), Partial Retention, Maximum Modification, or Enhancement.

SCS - Landscape Architecture Priorities - The priorities assigned are a screening system to determine the need for further professional landscape architectural input in future planning efforts.

3. Applicability:

The three procedures provide for a determination of visual quality and for objective input on the consideration of visual resources for future planning efforts. Implementing the procedures would require use of a landscape architect or someone trained in aesthetics. Guidance on application of the basic elements for evaluating landscape quality is limited. Detailed guidance may be found in the Smardon reference.

4. Advantages and Disadvantages:

These techniques provide procedures for determining a quality measurement for visual or landscape resources. A chief disadvantage of utilizing the procedures is that there is minimal guidance on implementation, and more importantly, the use of the basic elements used in the procedures were shown by Smardon to need refinement to improve their reliability.

5. Previous Uses:

6. Source/Contact:

Robert Ross, Bureau of Land Management, Washington, D.C. (202) 343-9353. Ron Tulley, Soil Conservation Service, Washington, D.C. (202) 447-7443
Forest Service, Washington, D.C. (202) 447-2520

1. Name:

Cultural Resources Task Force. 1981. "I. Literature Review and Archival Search" and "II. Synthesis and Regional Overview"

2. Description:

I. Literature Review and Archival Search

The use of existing data (indicators) in the pursuit of identifying properties of cultural resources is generally considered to be standard procedure at any level of investigation and is particularly useful at the reconnaissance level. However, the actual sources of data employed and their degree of employment vary considerably, even for similar projects by the same investigator. The purpose of this profile is to provide a standard list of literature and archival sources that should be reviewed when undertaking a project. The categories identified here should be considered as minimal ones potentially applicable to any project. At the same time, it must be recognized that there is almost no universal applicability except on the most general level, hence it is the responsibility of the investigator to determine where the greatest effort should be concentrated.

There are three major categories that should make up the existing data review. In broad terms these are: 1) interviews (oral), 2) archival search (written record), and 3) professional literature (narrative and analytical). Where circumstances allow, it is most productive to exploit all three of these major information sources in a feedback method allowing reinforcement and expansion. As an example, a collector or property owner often has information about previous professional investigations that have not otherwise been reported. This then allows a current investigation to pursue the data from the earlier work.

a. Interviews: Interviews are generally very rewarding and offer the best payback in time and money expended. A properly applied interview strategy would include:

(1) Collectors.

(2) Property owners and former owners.

(3) Local historical societies.

(4) County clerks (recorders of registrars).

(5) County tax assessors.

(6) County or city engineers (particularly when dealing with historic properties).

(7) Local government officials.

b. Archival: Written data are best pursued either concurrently with interviews or following them. Except in special circumstances, archival work done without consulting informants can result in a substantial amount of backtracking. With that caveat behind, one should also be aware of the danger of relying too heavily on oral interviews. While archival work is a good way to refine pictures presented in interviews, one must also beware of relying on written material without question. The following list of standard archival sources normally available should be considered on a project-by-project basis:

(1) National Register of Historic Places - In most cases, the Register only picks up those significant sites or structures that have a constituency supporting their recognition.

(2) National Architectural and Engineering Record - This is particularly useful for comparative background in evaluating structures. (It includes the Historic American Building Surveys.)

(3) Maps - Start with USGS 15 and 7½ minute quad sheets in as many updates as are available for the area of interest, then look at plot maps from different periods, early surveys, claims commissions, and the U.S. Government Land Surveys (Corps of Engineers Real Estate officers often have some of these data for lands acquired in fee simple title).

(4) Official land holding records - Early deeds and grants, also preemption and tax records which note owners, value of the land and type of improvements.

(5) State files - These vary considerably and it is best to seek the advice from the state historical society before venturing forth.

(6) Personal journals and diaries - These often take a long time to sift through but are worthwhile for site specifics in the historic period; local historic groups are typically the best source of these.

c. Professional Literature: Professional literature is rarely helpful for project specific information at the planning level. It becomes more useful as other data is gathered to provide an interpretive background or frame of reference. All of the following references can serve as aids in interpretation:

(1) National journals.

(2) Regional journals.

(3) Ethnographic materials.

II. Synthesis and Overview (National/Regional/Local)

To adequately evaluate cultural resources, available data must be synthesized and evaluated from national, regional, and local perspectives. This begins with the initiation of a study and is repeated as projects proceed to further stages of refinement. The following must be included in this overview.

a. <u>Existing Data</u>

(1) Geographically - What data are there concerning the geographical area of concern?

(2) Temporally - What data are there relating to specific periods of time that relate to the project area?

(3) Information for research topics - What research topics are currently being investigated in the area that might be related to data from the project?

b. <u>Data Gaps</u>

(1) Geographically - Are there geographic areas critical to the project where data is lacking?

(2) Temporally - Are there time periods in the project area that are not represented?

(3) Information for research topics - What research questions could be asked?

c. <u>Identify Future Study Needs</u>.

This is a synthesis of all of the above (I & II) and will identify what future work needs to be done and what questions need to be addressed.

3. <u>Applicability</u>:

The two procedures described assist in identifying the existing cultural resources in a study area. The procedures provide the information necessary to begin to formulate the EQEP evaluation framework showing the significant cultural resources. The interviews, archival search, and literature review identify the significant cultural resources based on the EQEP significance criteria. (National Register criteria are considered in a later procedure.) The Synthesis and Overview procedure brings together the existing knowledge concerning a study area's cultural resources and identifies areas where data are lacking. These two procedures fulfill the requirements of the Define Resource Phase in EQEP through specification of resources to be included in the evaluation framework.

1. Name:

Cultural Resources Task Force. 1981. "III. Field Reconnaissance-Identification and Inventory of Resources," "IV. Evaluation of Field Results," "V. Recommended Plan."

2. Description:

III. Field Reconnaissance - Identification and Inventory of Resources. The Cultural Resources Reconnaissance requires a field investigation of a representative portion of the area of potential environmental impact. It should be initiated as early in the feasibility study stage as possible. The primary goal of investigations at this stage of study is to gain a more specific knowledge of the range of cultural resources present within the planning area, and to make preliminary assessments of their potential significance. It is usually not possible at this stage to fully evaluate properties in terms of their eligibility or noneligibility for the National Register of Historic Places. However, it is essential that planners get an early assessment of the types, numbers, and potential significance of those resources.

A. Define Study Area. The study area should be defined in conjunction with all other relevant study needs, but the zone of impact for cultural resources may differ from that for other resources. Other preliminary tasks include:

(1) Initial description and graphic display of project alternatives and projected impacts.

(2) Evaluation of the environmental setting as related to past human usage.

B. Evaluate Alternative Field Sampling Methodologies. Each project and planning area will present unique problems which must be considered in framing the most appropriate and informative field sampling methodology to be employed. It is important that these (and all) investigations be structured by project-specific and explicit goal-oriented research designs in order to maximize information return. In shaping the research design it may be necessary to conduct, or incorporate into the research design, research into such background topics as:

(1) Area gemorphology, topography, soils.

(2) Environment, ecology, botany, available resources.

(3) Cultural and historical considerations (settlement patterns, native subsistence, local history, etc.)

C. Select/Develop Field Reconnaissance Strategy. Within the broader parameters of the research design and goals, it is necessary to tailor reconnaissance strategies and methodologies to project-specific situations, considering the following:

(1) Constraints, e.g., accessibility to sites, ground cover conditions, availability of time and funds, mapping and aerial photo coverage, excessive overburden on sites, etc.

(2) Selection and weighting of stratification variables

a. Cultural/environmental/ecological zonation of planning area.

b. Percent coverage requirements.

c. Level of existing information.

d. Anticipated impacts.

e. Resource types and temporal periods represented.

(3) Field methods (dictated by types of resources known or expected).

a. Informant interviews, archival research etc.

b. Surface investigations (controlled surface collection, noncollection).

c. Subsurface investigations (transect testing, coring/augering, backhoe testing, etc.)

d. Documentation (archival, photographic, etc.)

D. Implement Field Reconnaissance Strategy. This step should include limited site testing and documentation, and preliminary assessments of potential site significance against National Register or other relevant criteria.

E. Formulate Site Location/Evaluation Models(s). This should allow a generalized prediction of numbers and locations of sites within the planning area, as well as a preliminary assessment of the potential significance of those sites. This requires sound and seasoned professional judgment on the parts of cultural resource specialists and contractors.

IV. Evaluation of Field Results - In order to maximize the effectiveness of information gathered during the field reconnaissance, it is necessary to exercise innovative yet sound professional judgment in the evaluation and use of such data in the formulation of alternative project plans. The ultimate goal of this evaluation process is to generate an array of implementable planning alternatives which will result in minimal or no effect on potentially significant cultural resources, i.e., an array of "least damaging" plans consistent with all other planning objectives. Data evaluation methods which may prove useful are discussed below:

A. Estimate Site Density. Estimates of site density in different segments of the planning area can be useful in predicting the number of sites which may be affected by alternative plans. Site density projections should be used in conjunction with preliminary assessments of site significance.

B. Estimate Range of Site Types. It is essential to know what types of cultural resources may be affected by alternative plans. Different plans may affect primarily only one class, or a limited range, or resource(s) which may be more, or less, significant than other resource types present in the planning area. Convenient classes of resource types might include:

(1) Prehistoric sites (structured by temporal/cultural periods).

(2) Historic period sites.

(3) Architectural elements.

(4) Engineering elements.

C. Assess Potential Site Significance. There exists no universally applicable, reliable, or acceptable method of fully assessing site significance on the basis of limited field reconnaissance information. Corps planners and contractors must therefore rely heavily at this stage on professional experience, judgment, and knowledge of local, areal, and regional resource base. Preliminalry assessments of significance may be predicted on limited and often intuitive or subjective criteria of significance which would be subject to revision and change as more complete information becomes available. Preliminary criteria of significance may be tailored to local or regional conditions, and may consider individual resources on individual basis, or on a "resource district" basis. If applicable, the National Register of Historic Places eligibility criteria may also be utilized. The potential significance of all resource classes present must be assessed.

D. Assess Potential Project Impacts. To the extent possible at this stage of project planning, it is necessary to determine as closely as possible the nature and extent of effects likely to result from major project features still under consideration. It should be possible in most instances to determine whether project features will have severe, moderate, or no effects, or direct or indirect effects on cultural resources.

E. Compare Alternative Plans. Based upon full evaluation of field reconnaissance data, discussed above, it is important to compare the alternative plans and project features still under consideration for their relative effects on potentially significant cultural resources. The comparison of alternative plans includes comparison of the no-action future condition. In some cases, the no-action alternative could be more severe than the proposed alternatives. This task should include a tentative ranking of alternative plans based upon extent of cumulative effects. It should be possible at this point to begin consideration of project plan modifications which might reduce or eliminate effects on cultural resources.

V. Recommended Plan from a Cultural Resources Point of View. Based on the comparison of alternative plans, a plan is recommended.

3. Applicability:

The two procedures outlined above provide the field reconnaissance data necessary to predict the number and type of cultural resources present in a study area and to predict the impacts or effects of alternatives on the resources. The field reconnaissance strategy in conjunction with the site location model allows an estimation of the number of sites in the study area. By delineating the number and type of cultural resources, the impact of each alternative plan can be determined. The Evaluation of Field Results uses the predicted number and location of sites to evaluate the significance of the sites and the projected impacts of each alternative. After the effects of each alternative are projected, an alternative plan is recommended that is most desireable based on its effects on cultural resources.

Implementation of the Field Reconnaissance and Evaluation of Field Results procedures can provide the information on which to base the EQEP Inventory Resources Phase, the Assess Effects Phase, and Appraise Effects Phase. The estimates of site density and range of site types indicate the resources present for the Inventory Phase. These Inventory data allow potential impacts of each alternative to be predicted for the Assess Effects Phase.

At the level of Field Reconnaissance, the determination of significance of specific cultural resources and of effects on those resources is highly dependent on the professional experience and knowledge of the local and regional resource base. Without an Intensive Survey, the judgments of significance required in the Appraise Effects and Assess Effects Phases are based on technical criteria developed in IV.C Assess Potential Site Significance and the impacts identified in IV.D Assess Potential Project Impacts. In some cases, testing for National Register eligibility may also be undertaken.

1. Name:

Cultural Resources Task Force. 1981. "VI. Intensive Survey."

2. Description:

VI. Intensive Survey

A. Update Feasibility Report Data if Necessary. Normally, an Intensive Survey is implemented sometime after completion of the feasibility study. It may be necessary to revise the data contained in the feasibility study because of the following:

(1) Enough time (5 years or perhaps 2 in near-urban areas) has elapsed since completion of feasibility studies and alterations in terrain, ground cover, etc. have occurred.

(2) New developments in archaeological techniques/methodology have taken place since the earlier investigations.

(3) Additional archival data pertinent to the area have been discovered since feasibility report studies or additional archaeological research has been conducted by others since feasibility report studies which significantly alters previous conclusions or interpretations.

(4) There have been changes in design features or alternative plans since the previous study.

B. Define Project Area. Cultural Resource Investigations are normally limited to the geographic area encompassed by the project boundaries. The definition of the project area should be broken down into areas of impact priority and subsequent field work scheduled correspondingly, especially if actual construction is imminent.

In exceptional cases, cultural resources which are outside the actual boundaries but are specifically and significantly related to a site(s) within the boundaries may require special recognition on a case-by-case basis. The effect upon such sites must be recognized, but the authority to mitigate associated impacts would require special requirements and most likely separate legislation.

C. Evaluate Intensive Survey Methodology. Although a project boundary is a primary determinant in the area to be surveyed, different methodologies are available but no attempt at listing such topics is warranted here. However, thoughtful and knowledgeable consideration of the terrain, ground cover, access, and general environmental characteristics of the area to be surveyed should influence development and selection of the methodology to be used. The most critical desired end product to be achieved is the location and evaluation of all the cultural resources within the project area. Methodology of the survey should be tailored in response to the environmental and physical characteristics of the specific study area and direct project impacts. If gaps are left in the geographic areas site location and evaluation of significance, then an inherent weakness in the mitigation plan will occur, which in turn affects the quality, cost, and effectiveness of the ultimate mitigation program. Consequently, the location and evaluation of sites (surface and subsurface) to the maximum extent possible is necessary prior to developing the plan of mitigation. Too often some of the more important sites in project areas are not located until construction is well advanced and available funds are committed to other less significant sites which may not produce as much data. Early location and evaluation are critical if such trends are to be stopped.

D. Select and Develop Site Evaluation Strategies. This is the process of determining the most appropriate tests needed for making sound decisions concerning application of National Register criteria to the data resulting from the tests. The type(s) of testing to be performed should be based on

(1) Physical characteristics of known sites in the area which resulted from previous Field Reconnaissance findings, e.g., data/temporal gaps.

(2) Benefit/cost effectiveness for data retrieval.

(3) Maximum use of available data collection sources other than technicians (field and laboratory) trained to incorporate archaeological data obtained in routine soils analyses during borrow, access road, and dam site preparation will prevent or alleviate continued "accidental" finds of buried sites during construction. Because of the "sealed" nature of buried sites, they often possess a greater potential than surface sites which have been subjected to surface disturbances and weathering.

E. Implement Intensive Survey.

F. Establish National Register Eligibility.

G. Reassess Impacts, Establish Mitigation Priorities.

3. Applicability:

The Intensive Survey, normally occurring after the feasibility study, provides the necessary field data for determining eligibility for the National Register of Historic Places and developing a mitigation plan. In cases where potential impacts warrant, the Intensive Survey may be initiated during the feasibility stage. In such cases testing for National Register eligibility may be used as a basis for determining the significance of specific sites.

For an EQEP analysis, the Intensive Survey, using the results of the field surveys, provides an assessment of impact based on more intense field sampling than in the reconnaissance survey. The testing for National Register criteria provides more stringent criterion for determining significance.

1. Name:

Forest Service. 1974. "National Forest Landscape Management, Vol 2, Chapter 1, The Visual Management System," Washington, D.C.

2. Description:

This management system was developed to provide data on which to base visual quality objectives for Forest Service planning. The system develops inventory information about landscapes and then uses this information to develop Visual Quality Objectives, such as Preservation or Modification which determine the type or extent of activities allowed in the area.

The inventory data are the determination of Variety Classes and Sensitivity Levels for the area. The variety class of a landscape is an indication of the distinctiveness of the landscape. Distinctiveness is determined by comparing landscape characteristics to characteristics for that physiographic region. The visual characteristics or landscape components considered are land form, rock formations, water forms, and vegetative patterns. Those characteristics typical to an area are known as the visual character type. The characteristics of the visual character types of the Pacific Northwest, the area for which the technique was developed, have been described fully. Characteristics of other regions would have to be developed for determination of variety classes. While this appears a severe limitation to this approach, it is common to read references to "typical landscape for this river basin." Describing or defining the "typical landscape" of an area allows this process to be applied.

The determination of variety class is accomplished by developing rating criteria for each characteristic, e.g., vegetation, which are used to delineate distinctive, common, and minimal scenic quality. Scenic quality is based on variety in the form, line, color, and texture of the characteristics, using the visual character type as the frame of reference. The suggested process is to rate the Class B (common) features within the area. By determining criteria for Class B land form, water forms, etc., distinctive (Class A) and minimal (Class C) variety also become apparent. The variety classes are then mapped on a base map of the area.

The second part of the inventory deals with assigning sensitivity levels to the landscape. Sensitivity levels are used to describe the concern for scenic quality in the areas seen from primary and secondary travel routes. Assigning sensitivity levels would require having viewers and potential viewers express their major and minor concerns for scenic quality on the travel routes, use areas, and water bodies. Three levels of sensitivity are assigned based on the concerns expressed by potential viewers. The three sensitivity levels represent the acceptability of modification of an area.

The sensitivity levels and variety class classifications are used to develop management objectives and develop restrictions for development of Forest Service lands.

3. Applicability:

This technique can be used to assess the visual quality of landscapes within a study area. The use of the variety class classification could be used to measure and to describe the visual quality of an area. The use of this approach outside the Pacific Northwest is possible, especially if there are studies documenting the characteristic landscapes.

This process is suited to evaluate the visual quality of a large study area, e.g., a river sub-basin or small basin.

The use of the Sensitivity Levels procedure to identify visually sensitive areas is limited by the requirement for public input of concerns.

4. Advantages and Disadvantages:

This method of evaluating scenic or visual quality, as with other aesthetic techniques, has the disadvantage of relying on a high degree of subjectivity for its results.

Research to determine the reliability and validity of using the elements of line, form, color, and texture was performed subsequent to publication of these procedures. This research indicated that additional elements should be considered to increase the reliability of the technique. The research findings are summarized in the Smardon profile.

5. Previous Uses:

These procedures were used to develop Visual Quality Objectives for management plans for ten Forest Service areas in the Pacific Northwest.

6. Source/Contact:

Ron Tulley, Forest Service, Washington, D.C., (202)447-2520.

1. Name:

Hamor, Wade H. 1974. "Guide for Evaluating the Impact of Water and Related Land Resource Development Projects on Fish and Wildlife Habitat." Soil Conservation Service, Lincoln, Nebr.

2. Description:

This report formalizes a method to measure habitat quality based on professional judgment. The method uses on-site investigation of affected habitats as the basis for assigning a 0-1.0 quality value for each habitat type. The quality-value is multiplied by acreage (for terrestrial habitat) or by miles (for stream habitat) to give acre-values or mile-values. The basis for estimating the quality value is that the quality value is the estimated fractional value of the existing habitat with respect to its potential value if managed for wildlife. The acre-values and mile-values are used to calculate gains and losses of habitat due to a proposed project. The assessed quality value is used to calculate the required mitigation for losses due to a project.

The assignment of quality values, while based on professional judgment and experience, is formalized by determining the habitat conditions which constitute the 0-1.0 quality values. The basis for determining habitat conditions is usually the presence, absence, or condition of a few critical habitat variables or components. Examples of these components are distance to water, type and age of vegetation, and presence of mast bearing trees. It is on the basis of these variables that the quality value is assigned. Professional judgment is utilized to relate the importance of these habitat variables to the 0-1.0 scale. The assignment of quality rating and the factors to be considered in the rating is determined by the experience of those making the evaluation; the guidelines included with the report cover the six habitat types commonly found in the SCS area for which the method was developed, other guidelines would be developed for other areas.

In practice, this method requires two field surveys. The first survey is used to identify habitats of important, rare, or endangered species. The second survey is for the evaluation of the different habitat types and assigning the quality values. Both of these surveys are assisted by use of aerial photography to identify habitat types.

After the surveys and evaluations are complete, habitat gains and losses are calculated in terms of acre-values and mile-values. The change in acre-value or mile-values over the life of the project is determined. This change in value is used to determine the number of acres required for mitigation.

3. Applicability:

The methodology embodied in this report is a framework for evaluating habitat quality based on expert or professional judgment. The report lays out a systematic, tractable way to evaluate habitat quality. This method is very similar to the evaluation of habitat diversity found in the SCS 1977 profile. This evaluation of habitat quality differs from the Herin method in that the quality value is scaled rather than three categories.

This method for assessing habitat quality requires a minimum of fieldwork. The method requires a greater level of professional judgment than the Herin method, because habitat variables must be related to a 0-1.0 scale rather than setting only three categories of habitat quality.

4. Advantages and Disadvantages:

This method provides a rapid assessment of habitat quality with a minimum of data collection. Because the method is based on professional experience, evaluations may produce varying results due to differences in professional opinion and differences in scaling of the variables.

5. Previous Uses:

6. Source/Contact:

Soil Conservation Service, Lincoln, Nebr., (402)471-5307

1. Name:

Hayes, Robert L. 1981. "Estimating Wildlife Habitat Variables," FWS/OBS-81/47, Western Energy and Land Use Team, Fish and Wildlife Service, Fort Collins, Colo. (Prepared by Colorado Cooperative Wildlife Research Unit, Colorado State University, Fort Collins, Colo.).

2. Description:

This handbook was developed to provide a collection of techniques suitable for quantitatively estimating characteristics of habitat important to wildlife species within a sample area. The measurement techniques may be used to supply the data used in habitat suitability models or to provide an indication of quantity or quality conditions for use in EQEP. The techniques summarized are for measuring the habitat variables commonly measured in habitat modeling or studies. The handbook was written to be used in conjunction with documentation for sampling design, statistics, and modeling. The handbook is field-oriented, providing enough information about the technique without going into its theoretical basis. The handbook emphasizes techniques that:

a. Require relatively inexpensive equipment.

b. Represent the state-of-the-art.

c. Are useful in the field.

The handbook provides a glossary of the habitat variables commonly sampled in the field. The glossary contains one or more definitions of the variable, some common uses in studies or modeling, and references to techniques suitable for measuring the variable. The variables included in the handbook are grouped in five categories. The categories, subcategories, and the variables are included in the Extended Profile Section.

The section describing the techniques describes them in general terms, relating the measurement to specific habitat variables. The technique description identifies:

a. Information required for locating samples, collecting data, and reducing data to calculated results.

b. Accuracy/precision discussion. This includes a qualitative statement about the accuracy of the technique and discusses sources of error and how they can be minimized.

c. Application "notes". This provides guidance on the relative cost of the technique, the number of people required to apply it, and the types of vegetation or soil conditions which may cause problems in applying the technique.

d. User agencies.

e. Training requirements; the length of time required for one to become moderately proficient in the technique.

f. Equipment, with some indication of costs and an estimate of an average of the number of measurements that can be collected in a given time, or the amount of time required to make one measurement.

The techniques described in the handbook are listed in the Extended Profile Section.

Included as appendices to this manual are sections which address:

a. Locating random sample points, line transects, individual plants, and a group of plants.

b. Conversion factors.

c. Introduction to aerial photography applications to habitat variable estimation.

d. Remote sensing techniques for measuring habitat variables.

3. Applicability:

The techniques described in the manual provide measurement techniques to inventory habitat variables which may themselves be EQEP indicators or may be used as part of a model used for indicator measurement.

4. Advantages and Disadvantages:

The limitations of each technique are presented.

5. Previous Uses:

Agency use of the techniques is noted in the descriptions.

6. Source/Contact:

1. Name:

Headquarters, Department of the Army, CE. 1981. "Biological Indices" Draft Engineer Pamphlet. Washington, D.C.

2. Description:

This Engineer Pamphlet (EP) was developed to provide guidance on the choice and application of biological indexes. Biological or biotic indexes have been developed to concisely summarize various aspects of community or population structure. This EP documents biological indexes which have applicability for assessment and monitoring changes to the structure of aquatic communities. Many of the identified indexes have terrestrial applications.

For each of the indexes included in the EP, the following information is presented

a. General description.

b. Mathematical expression.

c. Recommended level of taxonomic identification.

d. Geographic applicability.

e. Computational devices required.

f. Statistical evaluation.

g. Use of the index (level of sampling required, recommended form of data reduction, interpretation).

The indexes summarized in this profile are the most commonly used indexes of species diversity. The index values produced by these indexes may be used in an EQEP analysis as a measure of community or population structure. The indexes included here have terrestrial and aquatic applications. Indexes of diversity are measures of heterogeneity of a sampled community. Species diversity has two components, species richness and evenness or equitability. Species richness pertains to the number of species present in the sampled population. Evenness or equitability refers to how the individuals are distributed among the species present. Most indexes have been developed from information theory. (A discussion of information theory is beyond the scope of this profile. See Lloyd reference under Source/Contact.)

The indexes summarized below enable the user to determine or estimate the species diversity of a biological community. The choice of specific index to use is dependent on a number of factors including time and manpower constraints in sampling, and the component of diversity, e.g., evenness, that is of interest. The indexes included here utilize mathematic formulae which can be easily handled with programmable calculators.

A. Brillouin's Index - This index is the preferred index for a collection or universe which is small enough that all the members of the universe can be collected and identified according to species. That is, the individuals included in the index are not considered a sample of some larger universe, e.g., invertebrates colonizing a substrate sampler. Brillouin's is a determined, rather than estimated index because the sample from which the index is calculated is considered to be the entire community. Brillouin's index takes the form:

$$H = \frac{1}{N} \ \ell n \frac{N}{N_1 \ N_2 \ \ .....N_s}$$

where

H = Brillouin's Index

N = the number of individuals in the universe

N_i = the number of individuals in the ith species, so that

$$\Sigma \ N_i = N$$

S = the number of species in the sample

Although designed primarily for use with species level identification, the index can be subdivided into hierachical values of diversity according to the classification of the members of the community. Sampling should be designed to ensure collection of representative species. Like most information theory indexes, Brillouin's has output in the log units used in the formulation. (The log units used, 2, 10, or e, are left up to the user.) Interpretation of index values is straightforward, increasing index values are indicative of increasing diversity within a population.

B. Shannon - Weaver (or Shannon - Wiener or Shannon) Species Diversity Index - The Shannon Index is the most widely used index. The index is used under the assumption that the community in question is infinitely large. The index is a function of relative species abundance within a community. Index values vary as a function of the number of species present, species richness, and how evenly they are represented, evenness. "Since this index is defined for average condition within a large collection, it is inappropriate for use with a collection which is small enough to allow all of its members to be identified and enumerated." (Brillouin's Index would be indicated in that case.)

The Shannon Index takes the form:

$$H' = -\sum_{i=1}^{S} P_i \log P_i$$

where:

H' = Shannon Weaver Species Diversity

S = the number of species in the sample

P_i = the proportion of the ith species in the sample

The index yields values in the log units specified by the user. The sensitivity of the index is decreased if identification is not to the species level.

The index has three properties which make it especially useful:

a. H' takes its maximum value when $P_i = 1/S$ for all i; and representatives of S are present in equal proportions.

b. Of completely even communities, that community with the greatest number of species (taxa) will have the greater value of H'.

c. A given H' can be subdivided into additive components.

C. Simpson's Index - This index was among the first information theory based indexes to be developed. The index is designed to be a measure of the probability that two randomly selected individuals from a sample will be members of the same species. This is therefore the inverse of diversity; as the diversity of a community increases, the Simpson Index correspondingly decreases. Simpson's Index is based on the assumption of an infinite sample.

Simpson's Index takes the form:

$$\lambda = \sum_{i=1}^{S} P_i^2$$

where

λ = Simpson Index

P_i = the proportion of the ith species in the community

S = the number of species in the community

Simpson's Index provides a measure of dominance, the inverse of diversity, and would thus be appropriate for communities under ecological stress, where one or a few species are assumed to predominate. As the inverse of community heterogeneity, the index decreases as species evenness increases. Simpson's Index reaches a minimum when $P_i = 1/S$ for all i. That is, the more highly diverse a community, the lower the Simpson's Index value.

A diversity index based on Simpson value has been developed. Simpson's Diversity Index is as follows:

$$\text{Simpson's Diversity Index} = -\log \lambda$$

where λ is the Simpson's Index as calculated above. The log units may be 10, 2, or e as in other information based indexes. The log values generated by Simpson's Diversity index are similar to the Shannon values and may be compared. Unlike the Shannon Index, Simpson's Diversity Index is unable to measure hierarchical, i.e., other than species, diversity. This limitation decreases its general applicability.

D. <u>Evenness Index</u> - Evenness is a function of the ratio between observed diversity and the theoretical maximum diversity. Although considered a part of overall species diversity, evenness or equitability may be considered independently. The evenness of distribution may be affected independently from changes in species richness. The evenness indexes most often used are Pielou's J and J'. The J index is used where the collection sampled represented the total population, that is, in cases where Brillouin's is the appropriate diversity index. The J' index is the evenness index to be used when the population has been sampled, when the Shannon or other information theory index is used. The Evenness Index is expressed as:

$$J' = \frac{H'}{H'\ max} = -\sum \frac{P_i \log P_i}{\log S}$$

where

J' = Evenness Index

H' = the observed diversity

$H'\ max$ = the theoretical maximum diversity

P_i = the proportion of a sampled community which belongs to the ith species

S = the number of species

The log base used is the choice of the user.

As the ratio between observed diversity (H') and the theoretical maximum diversity (H' max) evenness can be interpreted as a measure of the evenness of species distribution. The ratio reflects optimal evenness when J' equals one. Comparisons of evenness values are meaningful only when samples have been adjusted to a common number of individuals. Calculation of evenness index J is somewhat more complex than J' and is not included in the EP. (For calculation of J, see Hair under Source/Contact.)

E. Equitability Index - This index is a measure of the distribution of individuals among the species which is based on MacArthur's "broken-stick" niche model. The broken-stick model is supported by those who view numerical equality among species groups as being unrealistic. Those indexes of evenness which are based on 0-1.0 scales, therefore yield unrealistic measures of evenness. The MacArthur model is said to distribute individuals more realistically among the existing species. As with the Evenness Index, the Equitability Index is defined as the ratio of observed diversity to the theoretical maximum diversity. The observed diversity used could be any diversity index applicable to the sampling conditions. The maximum diversity based on MacArthur's model may be calculated by the following formula given by Pielou.

$$E(yi) = \frac{1}{S} \sum_{x=1}^{S} \frac{1}{x}$$

where

E(yi) = the expected size of the ith species (a measure of species is predicted share of the shared resource or community)

S = the number of species (taxa) in a sample

X = the number of individuals in the ith species

The Equitability Index has often been employed as an indication of water quality degradation in lotic communities. Values below 0.5 can indicate a degraded stream, while values ranging from 0.6 to 1.0 usually indicate a stream unaffected by oxygen demanding wastes.

3. Applicability:

The species diversity indexes cited above may be utilized to characterize the structure of aquatic or terrestrial communities by measuring overall species diversity and evenness. The indexes may be used to inventory existing conditions and monitor changes in the community structure over time.

4. Advantages and Disadvantages:

The diversity indexes cited above provide a concise method to measure and represent the ecological concepts of species diversity and equitability or evenness. The output from the information theory based indexes is at times difficult to understand for those unfamiliar with information theory.

The EP provides information on twenty-four biological indexes. Because of this number, only the basic information required for use is included. To properly use the index, more detailed information on sampling, interpretation, and theoretical aspects of the index may be required.

5. Previous Uses:

The use of each of the indexes is documented.

6. Source/Contact:

See also:

Hair, Jay D. "Measurement of Ecological Diversity," in Schemnitz, S. D. ed., Wildlife Management Techniques, Wildlife Society, Washington, D.C.

Lloyd, Monte, Zar, Jerrold H. and Karr, James R. 1968. "On the Calculation of Informational-Theoretical Measures of Diversity," American Midland Naturalist, Vol 79, No. 2 pp 257-272.

Pielou, E. C. 1975. Ecological Diversity. John Wiley, New York.

Jim E.Henderson, Waterways Experiment Station, FTS 542-3305, (601) 634-3305

1. Name:

Herin, Kenneth C. 1977. "Wildlife Assessment, Doniphan County, Project No. 36-22-RF-092-5(11)," Environmental Support Section, Engineering Series Department, Kansas Department of Transportation, Topeka, Kans.

2. Description:

This technique is a somewhat qualitative method relying heavily on professional judgment to determine habitat quality. This technique makes use of aerial photography to delineate the different vegetative or habitat types. The delineated covered types are then assigned to categories based on the value to wildlife. The classification of the habitats are determined through professional judgment of biologists familiar with the area. In the development of this method, the following categories were used:

Category I - Areas of greater value to wildlife because they involve perennial plant and cover associations. Such areas may include woodlands, grass meadows, and cropland in proximity.

Category II - Areas similar to Category I, but because of isolation, smaller size or absence of other wildlife factors, they are not as important to area wildlife. A large cropfield between two Category I areas is typical of this category.

Category III - Areas characterized by lack of diversity or permanent, quality cover types. Examples of this category are cropfields, monoculture rangeland, or urban areas.

After the impact areas are classified by categories, field work is done to verify categories and observe factors relating to quality. The result of the analysis is a map of the study area with each vegetative type categorized according to its value to wildlife.

Because this method is based on professional judgment and the vegetative type distinguished on aerial photographs, this technique is extremely flexible. The categories used for quality determination are determined by the professional.

3. Applicability:

This technique provides a method to evaluate habitat quality for early planning studies when little ground-truthing or sampling has been accomplished. The method formalizes the professional judgments of the wildlife biologist about the value of the different cover types for wildlife. The analysis thus evaluates the vegetative types for wildlife in general (as in a Habitat Evaluation System analysis) and not for specific species.

4. Advantages and Disadvantages:

The qualitative analysis used in this method provides a rapid assessment of habitat quality which makes extensive use of the professional experience of biologists familiar with the area in question.

5. Previous Uses:

This method was developed for the assessment of highway rights of way in Kansas.

6. Source/Contact:

Kenneth C. Herin, Environmental Services, Kansas Department of Transportation, Topeka, Kans. (913) 296-2271

1. Name:

Hulbert, Stuart H. 1971. "The Nonconcept of Species Diversity: A Critique and Alternative Parameters," Ecology, Vol 52, No. 4, pp 577-586.

2. Description:

This article presents a number of so-called species composition parameters that were developed to measure or estimate the species diversity found in a sampled population. The species composition parameters are used to calculate estimates of the number of species in a sampled population and the proportion of encounters by an individual which are interspecific (as opposed to intraspecific). The species estimate is used to estimate the number of species expected in a population based on the species richness, i.e., number of different species and number of individuals of each species. The estimate of interspecific encounters is of interest in considering such phonomena as predator-prey relationships.

This article does an excellent job of identifying a number of issues relating to diversity indexes, their calculation, and interpretation. The interpretation of the different diversity indexes which have been developed is somewhat confusing. The confusion is clarified by considering species diversity to be a function of (1) the number of species present, that is, species richness or species abundance and (2) the evenness with which the individuals are distributed among these species, that is, the species evenness or species equitability. To remain meaningful, the term species diversity should be restricted to the dimensions of species richness and species evenness. A number of so-called diversity indexes emphasize only one of the components of diversity. Most often, species richness is equated with species diversity. Even though "species diversity and species richness are often positively correlated, e.g., along latitudinal gradients, such positive correlation is neither a biological nor a mathematical necessity; gradients can exist along which increases in species diversity are accompanied by decreases in species richness." The Shannon and other diversity indexes have been criticized because they are "insensitive to the rare species." Hulbert points out that as a measure of community structure, diversity indexes would be affected to a lesser degree by rare species because the rarer species actually are minor components of their community.

Consideration of species richness often mixes or confuses numerical species richness with areal species richness. Aerial species richness is more properly referred to as species density. The use of species richness is more properly restricted to numerical species richness, that is, the number of species present in a collection containing a specific number of individuals or, possibly, amount of biomass. The species richness of a sample or collection will increase as the size of the sample increases. While this causes no problem when considering only one area, it complicates the comparison of indexes of different samples. For this reason the species richness parameter developed by Hulbert has the effect of standardizing the sample size. This parameter takes the form

$$E(S_n) = \sum_{i=1}^{s} \frac{\binom{N - Ni}{n}}{\left(1 - \frac{N}{n}\right)}$$

where $E(Sn)$ = expected number of species in a sample of size n

n = standardized sample size, i.e., the number of individuals in the standarized sample

s = number of species

Ni = number of individuals in the ith species ($N1, N2. . . Ns$)

where $\binom{a}{b} = \frac{a!}{(b!(a - b)!)}$

Calculation of $E(S_n)$ assumes a random sample of individuals has been taken without replacement, i.e., an individual will only be sampled once. This formula requires that all individuals in a sample be identified, although identification to the species level is not required.

This formula has the effect of reducing the sample size of a larger sample so that $E(S_n)$, the expected number of species, may be directly compared with the number of species in another sample. Multiple samples may all be standardized to the same size for comparison of species richness at different sites or locales.

To compare the species richness of two samples, species richness curves may be developed. These curves plot the expected number of species against the standardized sample size (n vs $E(S_n)$). These curves are to be considered species richness curves and not, as sometimes cited in the literature, species diversity curves. Samples may have similar diversity indexes, but quite different species richness curves. Calculation of enough $E(S_n)$ values to plot a curve will show that the species richness curve rises rapidly at first and then flattens out. This is due, in part, to the effect of increasing the sample size, so that at sufficiently large values of n, the results of richness comparisons tend to stabilize. Because of the stability of richness comparisons at larger sample sizes, it is often desirable to compare $E(S_n)$ values calculated for some high, standardized value of n. This is especially useful when correlating species richness with other factors. By use of the $E(S_n)$ and species richness curves, comparison may be made on the species richness of samples of differing sizes.

The other species composition parameters developed by Hulbert are similar in concept to the many diversity indexes based on information theory. Several of these indexes deal with the number of encounters an individual has with individuals of the same species (intraspecific encounters) and encounters with other species (interspecific encounters). The conceptual basis of these indexes is important when considering such things as predator-prey stability. These indexes take the form of

$$H' = - \sum_i \frac{N_i}{N} \log \frac{N_i}{N} \text{ (Shannon Index)}$$

and

$$H = \frac{1}{N} \Sigma \log \frac{N!}{Ni!}$$

These indexes produce diversity measures in terms of the log units (which can be 2, 10, or e). The output of these indexes is in log units (2 = binary or bits, e = natural or nats, 10 = nits) per individual. Unfortunately, the significance of numbers of bits per individual is sometimes unclear. The number of bits (nits, nats) per indivudual is related to a measure of diversity per individual in the sample. The greater the number of log units, the greater the diversity in the sample.

To provide the same type of interspecific encounter information in a measure with more meaning than bits per individual, Hulbert developed the Proportion of Interspecific Encounter statistic Δ,(PIE).

$$\Delta_1 = \sum_{i=1}^{s} \frac{Ni}{N} \frac{N - Ni}{N - 1}$$

$$= \frac{N}{N - 1} \quad 1 - \sum_{i=1}^{s} \pi_i^2$$

where Ni = number of individual of the ith species in a community (or collection)

$N = \Sigma Ni$ = total number of individuals in the community

$\pi_i = Ni/N$

s = number of species in the sample

The value of Δ_1, the probability of interspecific encounter is the proportion of potential encounters that are interspecific.

In terms of competition of species in the same trophic level, Δ_1 may be interpreted as the importance of interspecific competition relative to total competition. Then $1 - \Delta_1$ represents intraspecific competition. Such an interpretation obviously equates potential encounters with potential competition.

The consideration of distribution of the numbers of individuals among the species present, species evenness, may be determined using Δ values. Species evenness is usually defined as the ratio of observed diversity to maximum diversity. (Maximum diversity is said to occur when the species in a collection are equally abundant). Two types of evenness measures most frequently used are

$$V' = \frac{\Delta}{\Delta \text{ max}}$$

and

$$V = \frac{\Delta - \Delta \text{ min}}{\Delta \text{ max} - \Delta \text{ min}}$$

where Δ = observed value of the parameter

Δ max = value parameter would assume if all species s were equally abundant

Δ min = value parameter would assume if one species was represented by N-(S + 1) individuals and the other species by one individual each.

Species evenness may readily be calculated for Δ by calculation of Δ_{max} and Δ_{min}.

Meaningful parameters for individual species (to compare with the log units) may be developed utilizing the PIE and other parameters. However, the only individual parameter that is readily understood as significant is Δ_{ij}, the proportion of potential encounters that are interspecific for an individual in the jth species

$$\Delta_{ij} = \frac{Nj - 1}{N - 1}$$

$$= \frac{\pi_j - \frac{1}{N}}{1 - \frac{1}{N}}$$

where π_j = relative abundance of species j .

These parameters can be used to compare the environments of different species in the same community and of the same species in different communities.

3. Applicability:

The $E(S_n)$ and PIE parameters developed by Hulbert provide measures of species richness, i.e., estimated numbers of species, and species evenness. The development of these measured appears to be more meaningful than other information theory based indices.

4. Advantages and Disadvantages:

5. Previous Uses:

6. Source/Contact:

Stuart H. Hurlbert, 10814 Bar X Trail, Route 15, San Antonio, Tex. 78228

1. <u>Name</u>:

Leopold, Luna B. 1969. "Quantitative Comparison of Some Aesthetic Factors Among Rivers," U.S. Geological Survey Circular 620, U. S. Geological Survey, Washington, D.C.

2. <u>Description</u>:

Leopold's aesthetic evaluation technique is among the best known techniques for addressing aesthetics in water resources planning. The procedures assess aesthetics of project sites by determining the uniqueness of various resource factors and by rating the aesthetic characteristics of the factors. This technique is a method for quantifying elements of aesthetic appeal in a study area. Using this technique, comparisons of the aesthetics of proposed project sites can be made. The basis for comparison is those features of the landscape which influence judgments about the aesthetics and human interest in the area. In this study, 46 factors were selected and grouped into 3 categories: physical; biological and water quality; and human use and interest. All factors, whether measured or estimated, were assigned numerical values on a comparative scale of one to five (See Table 1, Extended Profile Section).

The ranking scheme consists of two parts which separately determine:

<u>a</u>. The relative uniqueness of each factor for each site considered, and

<u>b</u>. The relative uniqueness of each site when the unique qualities are arranged in order of aesthetic interest.

The first part is accomplished by assigning each site factor a uniqueness ratio. If a site factor is, for example, one among 12 of the same category, the site shares this character with 11 others. Its uniqueness ratio then is low, 1:12 or 0.08. If no other site shares the same category position, then the site has the highest possible uniqueness ratio, 1:1 or 1.0. The uniqueness is thus defined on a scale of 0 to 1.0.

The second part of the ranking scheme involves arranging the sites in an order based on the subtotals for the three groups of factors, physical, biological, and human interest and on the sum of all three (Tables 2 and 3, Extended Profile Sections).

A visual picture of the position of various sites given the three uniqueness categories can be shown as in Figure 1. The summed uniqueness ratios for human interest factors and for biological factors respectively form the Y and X axes and the sum of the ratios for physical uniqueness is specified next to each plotted point.

3. Applicability:

The procedures described by Leopold measure the aesthetic uniqueness of the three categories of factors for project sites. These procedures may be utilized to develop baseline assessments of aesthetic quality. These procedures are a measurement technique for addressing the aesthetic attribute of EQEP by providing a method to measure aesthetic uniqueness of the sites.

4. Advantages and Disadvantages:

Advantages are as follows:

a. Most of the necessary information will have been gathered or can easily be gathered during the study area inventory and description of the baseline conditions activities.

b. This method appears to be easy to implement.

c. The original application was site selection of a power plant. It could easily be adapted for use in any project, structural or nonstructural, where aesthetic impacts may take place.

Disadvantages are as follows:

a. The choice of factors to be used as well as the degree or category assigned are subject to individual judgment and dependent on the study area.

b. This method does not distinguish between areas that are uniquely good and those uniquely bad.

c. The factors, though weighted equally, may not be of equal importance.

5. Previous Uses:

This circular documents use of these procedures to assess aesthetics in the Hells Canyon area, Idaho.

6. Source/Contact:

1. Name:

Odum, Eugene P. and Cooley, James L. 1980. "Ecosystem Profile Analysis and Performance Curves as Tools for Assessing Environmental Impact" in "Biological Evaluation of Environmental Impacts," FWS/OBS-80/26, Fish and Wildlife Service, Washington, D.C.

2. Description:

This article proposes two assessment tools for determining ecosystem impacts: the ecosystem profile analysis and performance curves. These tools provide an ecologically based impact assessment approach. Rather than focusing on factors such as dissolved oxygen and species lists, these tools seek to incorporate holistic, integrative functions of the environment into the analysis. Thus, the holistic approach is based on measurements of system properties. Although system properties may be more difficult to measure than single properties, the total assessment time and expense may not be greater because a few well-chosen systems measurements can yield more information as to the overall ecological quality than numerous miscellaneous factor measurements. In addition, inclusion of a few "red flag" components, factors or species which are of special concern, e.g., endangered species, a heavy metal or organic poison, has been found effective for assessment purposes because impacts of these factors are significant for public concerns or public health reasons.

To illustrate the difference in the two approaches, the paper includes a comparison, reproduced below, of component and ecosystem approaches to the assessment of a body of water. The factor-level measurements are baseline or standing state physical and biological factors. They are usually measured because they are said to be indicators of perhaps water quality or some other broader system dimension. The ecosystem-level measurements are indicators of important biological functions.

Factor-Level Measurements (Standing States)	Ecosystem-Level Measurements (Dynamic States)
Dissolved Oxygen (D.O.)	Diurnal Oxygen Metabolism
Dissolved Phosphate	Phosphate Turnover Rate
Phytoplankton Biomass	Chlorophyll Concentration (as index to primary production)
List of Species	Indexes of Species Diversity
Density of Fish	Fish Production

Ecosystem profile analysis combines measurements of community metabolism and species structure for assessment. The community metabolism parameters are indicators of the metabolic functions of the ecologic community. These metabolic functions will change in response to stresses or changes to the ecosystem. The species structure is assessed through determination of diversity indexes. These community metabolism parameters and diversity indexes yield more information than similar factor-level analysis. For instance, measurement of diurnal oxygen will give an indication of the relationship of respiration and photosynthesis, determining whether the community is autotrophic, heterotrophic, or steady-state. Diversity indexes for species give an indication of community structure, giving more information than merely a list of species.

Three types of diversity indexes are actually used, an evenness index, a species richness index, and a habitat diversity or vegetation diversity index. Projected changes are incorporated and the predicted change in the index is calculated. The use of diversity indexes, and specifically their interpretation, is the subject of some controversy. It is for this reason that indexes which emphasize the different aspects of diversity, i.e., species richness and evenness, are used. Using both types of indexes is believed to yield more information than using a single index. In addition, the so-called dominance-diversity curves may be used in conjunction with or in place of the diversity indexes.

Dominance diversity curves are developed from census data on a population. On a log-scale, the number, biomass, or other indicator of species found in the sample is plotted in order of relative abundance (number of individuals on one axis, species on the other axis). The evenly spaced points are then connected to form a smooth curve. One part of the curve depicts the relative position of the most important or dominant species and the long trailing part of the curve depicts the number and relative standing of rare species. The shape of the resulting profile is significant because it can be related in some cases to the degree of disruption or encroachment on a habitat. For instance, the dominance-diversity profiles for benthic macroinvertebrates take on distinct forms for unpolluted, moderately polluted, and polluted streams.

Use of dominance-diversity profiles and diversity indexes in conjunction with indicators of ecosystem metabolism provides the ecosystem profile analysis with the specific analytical parameters to evaluate ecosystem changes in a superior way to the evaluation of factor-level analysis. The impact of a proposed action is shown by the projected changes in community metabolism and species structure. The changes that occur with different perturbations of ecosystems, e.g., fertilization of old fields or stream pollution, have been documented by changes in such things as primary production, biomass, species richness, and vegetative diversity.

3. Applicability:

Use of ecosystem profile analysis for EQEP analysis provides a way to incorporate more ecosystem-level measures into the evaluation process. The use of the ecosystem-level measurements must be planned early in the planning process so as to place proper emphasis in the data collection.

4. Advantages and Disadvantages:

The use of ecosystem profile analysis measurements yields evaluation of the dynamic character of the ecosystem rather than the standing state analysis provided by factor-level measurements. The increased information content from the ecosystem-level measurements is the result of the sometimes more costly in time and money, collection of data required for ecosystem-level measurements.

5. Previous Uses:

6. Source/Contact:

1. Name:

Ott, Wayne R. 1979. Environmental Indices - Theory and Practice, Ann Arbor Science, Ann Arbor, Mich.

2. Description:

This book is a reference for users wishing to apply indexes to environmental analysis. It is also intended to familiarize members of the general public, regulatory officials, and environmental specialists with the basis for and the limitations of environmental indexes. The initial section introduces the reader to the idea of using simple communicative approaches, such as environmental quality profiles, to present environmental data. The national monitoring activities that generate the data are described, and the difficulty of constructing environmental damage functions is discussed. (Environmental damage functions are functional relationships which show the relationship between a specific level of pollutant and its effect on man and the environment, e.g., sulfur dioxide levels and acid rain, and their effects).

The conceptual framework that is the basis for the majority of existing environmental indexes is explained. This framework is used to discuss the air quality and water quality indexes which have been developed. The section on air pollution indexes, in addition to analyzing and comparing them with the framework, also gives a detailed summary of the historical evolution and scientific basis for the Pollutant Standards Index (PSI), which has been developed for uniform application throughout the United States. The section on water pollution indexes utilizes the theoretical framework and concepts explained in the introduction to discuss the water quality indexes which have been developed. Design principles for an ideal water quality index are presented and a candidate index structure is developed. In both the sections on air quality indexes and water quality indexes, the current index usage patterns in the United States are described in detail. The final chapter presents conceptual approaches, such as quality of life and environmental damage functions that extend beyond the traditional fields of air and water pollution.

3. Applicability:

The book can serve as a useful guide or reference source to the environmental specialist desiring to employ environmental indexes. Environmental indexes could be utilized in the Inventory Resources Phase of EQEP to measure the quality aspect of significant resources.

4. Advantages and Disadvantages:

The book presents a thorough overview of environmental indexes. It is written in a coherent, easy-to-understand format, with accompanying graphs, tables, and references to clarify the text. Unless an index comparable to the examples listed in the text is developed, however, users will require a more detailed presentation of the index. Although the author intends for the book to be written so that the general public can find the concepts presented comprehensible, the complexity of some of the indexes eliminates that portion of the public unfamiliar with the mathematics and the scientific methods involved.

5. Previous Uses:

6. Source/Contact:

See also:

Ott, Wayne R. 1978. "Water Quality Indices: A Survey of Indices Used in the United States," EPA-600/4-78-005, Jan 1978, Environmental Protection Agency, Washington, D.C.

Thom, G. D., and Ott, Wayne R. 1975. "Air Pollution Indices--A Compendium and Assessment of Indices Used in the United States and Canada," Council on Environmental Quality, Washington, D.C.

1. Name:

Smardon, Richard C. 1979. "Prototype Visual Impact Assessment Manual," School of Landscape Architecture, State University of New York, Syracuse, N.Y.

2. Description:
This manual expands the Visual Resource Contrast Rating (VRCR) technique (see BLM Profile) and provides detailed guidance on implementation of the Contrast Rating technique. This revision of the technique is based on a two-year study to determine the reliability and validity of evaluation elements used. The testing indicated that a number of changes are necessary to improve the reliability of the Contrast Rating technique. This manual explains the changes and defines the elements used in visual impact assessment. The explanation of the visual impact assessment elements or variables provides enough guidance to be implemented by a field planner or landscape architect. This manual sets out both Basic and Detailed procedures, depending on the complexity of the project. In addition, a qualitative procedure is provided which uses the same basic elements for evaluation.

The basic premise behind the contrast rating technique is that "the degree to which a management activity adversely affects the visual quality of the landscape depends upon the amount of visual contrast that is created between the activity and the existing landscape character." The contrast rating method determines visual impact in the following way:

a. Description of the existing landscape components in terms of the basic visual elements.

b. Simulation of proposed changes to the landscape.

c. The contrast that occurs as a result of the modification is then rated based on the simulation.

In the testing of the concepts of the VRCR Manual, it was found that the elements of scale and spatial character should be added to the basic elements of form, line, color, and texture, making a total of six basic elements to be considered. This manual defines in detail each of the elements in a concise, clear summary. The summary (1) explains variations in the element, such as the types of the element Line are edge, band, silhouette, and (2) delineates the constituent subelements. For instance, the element Texture has as subelements Grain, Density, Regularity, and Internal Contrast. To assist the user in describing a landscape, a suggested vocabulary is included to assure accurate characterization of the element. There is a discussion of variable effects, such as distance, atmospheric conditions, or illumination which may affect evaluation of the element.

It was felt that addition of the elements of scale and spatial character to the contrast rating technique made the concept of contrast alone inadequate. For this reason, the concept of visual dominance has been added to the rating system. Visual dominance is the relative dominance of a modification over its setting. Visual dominance is determined by rating scale dominance and spatial dominance. Scale dominance is a measure of how dominant a modification is in a landscape due to the size or scale of the modification. Spatial dominance is an indication of how dominant a modification is due to its location or placement in the landscape. A modification may be more dominant in a specific landscape setting due to the spatial position, e.g., elevation of the project, the backdrop for the project, or spatial composition of the landscape.

Assessing the visual impact of a proposed modification is accomplished through simulation of the project in the existing landscape. A number of visual simulation techniques are available, and are summarized in the BLM Visual Simulation Technique profile. The simulation of the project is used as the basis for evaluating the degree of contrast for the elements and the dominance characteristics.

Utilizing the prototype visual impact assessment method described in this manual results in a measure of visual impact severity based on visual contrast, spatial dominance, and scale dominance. Visual contrast and dominance values are weighted differentially based on their importance for determining visual preference. It was found that the weighting scheme set out in the original VRCR Manual should be flexible and it is possible to assign varying weights to the contrast and dominance values. It was determined that generalized weighting may be appropriate and that the following order of importance is more accurate in determining the degree of visual impact than the weights set out in the VRCR system:

Scale dominance - most important
Color contrast
Form contrast
Spatial dominance
Scale contrast
Line contrast
Texture contrast - least important

The rating of visual impact severity is produced by summing the weighted contrast ratings and the ratings for spatial dominance and scale dominance. Depending on this sum, the visual impact severity of the proposed project is rated as severe, strong, moderate, weak, or negligible.

There are qualitative procedures included which may be used instead of those outlined above. The qualitative procedures use the two most important elements, Scale Dominance and Color Contrast, to determine Visual Impact Severity.

This manual outlines procedures for what is termed Basic and Detailed assessments. The Basic assessment is to be used for visual impact assessment of relatively commonplace management measures, such as water tanks, dirt roads or other small projects with low to moderate visual sensitivity. The Detailed procedures are to be used in unusual projects or those with high visual sensitivity. The chief difference in the two procedures is the level of detail required in the rating procedure and the need for more accurate simulations in the Detailed procedure.

3. Applicability:

The visual impact assessment procedure described is a systematic method for visual impact assessment. The procedure described is methodologically defensible because the variables utilized for assessment have been shown to be the important variables for determining visual impact severity. The guidelines are sufficiently detailed so that the procedure could be applied by a field planner.

These procedures provide a method for addressing the impact on visual resources. The impact on aesthetic or visual resources may be measured in terms of visual contrast and visual dominance. Thus, the prototype procedures are a way to address all activities within the Evaluation of Effects step for visual resources.

4. Advantages and Disadvantages:

The procedure described for visual impact assessment is the most comprehensive of the agency techniques reviewed. The guidelines provided for evaluating the contrast and dominance elements are complete and readily understood by the planner. The only limitation on the procedures may be the simulation of the proposed project in the landscape, however, the BLM manual on Visual Simulation provides simulation methods which may be readily implemented in a District.

5. Previous Uses:

Case studies of previous uses of both the Basic and Detailed procedures are included in the manual.

6. Source/Contact:

Dr. Richard C. Smardon, School of Landscape Architecture, College of Environmental Science and Forestry, State University of New York, Syracuse. (315) 470-6576.

1. Name:

Soil Conservation Service. 1977. "Illinois Environmental Assessment Procedure", Champaign, Ill.

2. Description:

This report describes a technique to measure habitat diversity. This technique is less data, manpower, time, and cost intensive than other techniques to measure habitat diversity, such as that described in the Asherin profile. In addressing the structural aspect of the Ecological attribute in EQEP, it may be desirable to use an indicator such as the diversity of wildlife species. This technique is developed on the premise that wildlife diversity or variety is related to habitat diversity and "Optimum habitat conditions in the planning area are those that provide for the greatest variety in wildlife species." Habitat diversity is equated with vegetative diversity, and is thus detectable from aerial photography.

The development of the wildlife Habitat Acre-Values is the crux of this measurement technique. The Habitat Acre-Values are the value for wildlife of the habitat type due to the diversity found within the habitat type and due to its proximity to other habitat types. The Habitat Acre-Values are determined in the following way. Aerial photography of the study area is used to delineate the different habitat types. Habitat types are mapped into contiguous habitat units. The technique recommends use of 1 inch to 660 ft photography. The photography is used to delineate habitat types. The specific application for which this technique was developed recognized four vegetative habitat types: Woody, Herbaceous, Grain and Seed, and Water.

Using the mapped habitats, the following information is developed.

a. Acreages of each habitat type.

b. Management values for each habitat type.

c. Diversity values for each habitat type.

The acreage of each habitat type can be determined by using a planimeter on the maps.

The determination of management values incorporates habitat acreage and management acre-value for each habitat type. Management values express habitat quality, taking into consideration such values as

a. Species composition, age and size of vegetation.

b. Degree of grazing or use.

c. Severity of pollution or other dysfunctional characteristics.

The management acre-values are based on the diversity in structural composition (i.e., age, size, variation of species) found in each habitat type. Criteria were developed to assist in assigning a management acre-value for each habitat unit.

After each habitat unit is assigned a management acre-value, the management acre-values for each habitat type are summed and divided by the total number of acres for the habitat type. This yields the mean management acre-value for each habitat unit.

The diversity value is calculated by measuring the mean distance to each of the other habitat types. A number of points are randomly selected in each quarter section of the mapped area. The distance in feet from each point to the other three habitat types is measured. The mean distance for each habitat type is then calculated. The mean distance in feet is converted to a diversity acre-value utilizing a 0-1.0 scale. The scale was developed by "analyzing a hypothetical optimum" habitat distribution. Optimum is defined as a situation in which the four types of habitat occur in alternating 10-acre units with woody hedgerows surrounding each unit of herbaceous, water, or grain and seedcrop habitats.

After the management values and diversity values have been determined, the Wildlife Habitat Acre-Value for each habitat type is calculated as the product: (mean management acre-value) (mean diversity value) (acreage of each habitat type). The Wildlife Habitat Acre-Values for each habitat type are calculated and then summed. This summed value, the Weighed Wildlife Habitat Acre-Value, represents the habitat quality of the study area.

3. Applicability:

This technique is a habitat based methodology which measures habitat diversity without regard to species use of the different habitats. The technique treats all species equally important.

Professional experience with the characteristics of the habitat types in an area is required to develop the management-value and diversity values for habitats other than the four types for which the technique was developed. The measurement of habitat diversity using this method can be used to evaluate habitat quality when an inadequate data base exists for using habitat suitability models or other species oriented evaluations.

4. Advantages and Disadvantages:

This technique to measure habitat diversity has the advantage of requiring a minimum of fieldwork. The technique does require professional knowledge of the habitat types being evaluated to determine the management values.

5. Previous Uses:

This technique has been utilized by the Soil Conservation Service in Illinois.

6. Source/Contact:

1. Name:

Soil Conservation Service. 1978. "Procedure to Establish Priorities in Landscape Architecture," Technical Release No. 65, Washington, D.C.

2. Description:

This technical release sets out procedures for developing input on visual resources to be used in early planning decisions. The input is in the form of landscape or visual resource priorities for a particular area, site, or region. The priority assigned is an indication of visual resource quality and the level of landscape planning required for future developments. The priorities are assigned on the basis of three factors, Visual Resource Quality, Landscape Use and Visibility.

Visual Resource Quality (VRQ) is a rating of the uniqueness or desirability of a visual resource made within the context of the surrounding landscape or region. The visual resource components considered in rating VRQ are Landform, Vegetation, Water, Structures (man-made development), and Combinations (the consistency or compatability of combinations of visual elements). Resource components are assigned a high VRQ rating if the component exhibits a high level of diversity in the visual elements, such as diversity in side slope, color diversity, texture diversity, diversity in vegetation, or diversity in size. Criteria are presented for assigning ratings to each of the landscape components. VRQ for a landscape is rated as distinctive, average, or minimal depending on the diversity of landform, vegetation, and other landscape components.

The use of landscape may influence perceptions of visual quality, although the two are separated for analysis. Landscape Use (LU) is rated by evaluating direct, indirect, and combinations of use. LU is rated as being Most Important, Important, and Minimal Importance by rating criteria such as cultural value, level of control on uses, and intensity of use.

Visibility evaluation (V) is an estimate of the number of viewers, their probable expectations and their relative ability to see from the location. A rating of High (V^3), Average (V^2), or Low (V^1) visibility is determined by rating criteria that evaluate the number, frequency, and duration of viewers; expectations of viewers, e.g., homeowners versus transient or nontourist; and the location and viewer's position. High visibility ratings are given to landscapes viewed from places that viewers would have high visual expectations, such as home, major highways, and scenic areas.

The assignment of priorities is accomplished by using numerical scores for the three rating levels of each factor and summing the rating levels.

That is, Priority Rating = VRQ + LU + V.

The possible 3-9 scale is divided into three ranges of Priority Areas.

3. Applicability:

The technique for assigning priorities is a method to assign a value to landscape quality. The rating criteria emphasizes the interaction of man, e.g., Landscape Uses, Viewer's Expectations, with the landscape and are appropriate for use in agricultural, rural, or suburban environments; this reflects the needs of the sponsor, SCS.

This technique for evaluating landscape quality could be used to characterize landscape in Problem Identification. The technique fulfills requirements of the Survey Existing Conditions Activity (Inventory Resources Phase) of EQEP for the visual resources of a study area.

The techniques were developed for use in early planning stages.

4. Advantages and Disadvantages:

This technique is a relatively simple method for evaluating landscape resource quality. It incorporates man's interaction in the evaluation. The guidelines for implementing the described procedure may not be detailed enough to be applied by someone other than a landscape architect. After the publication of the procedures, research was done to determine the reliability and validity of the visual elements, color, texture, etc. Research indicated that the specific elements used to evaluate landscape quality should be changed. This research is summarized in the Smardon profile.

5. Previous Uses:

6. Source/Contact:

Ron Tulley, Soil Conservation Service, Washington, D.C.
(202) 447-7443

1. Name:

Thomas, Jack W. 1979. "Wildlife Habitats in Managed Forests, the Blue Mountains of Oregon and Washington," Agriculture Handbook No. 553, Forest Service, U. S. Department of Agriculture, Washington, D.C.

2. Description:

The system described in this report was developed to assist Forest Service personnel in predicting impacts of management practices. This method relates successional stages to the habitat requirements of terrestrial vertebrates. This method relates the habitats used by the species found in the Blue Mountains with the vegetative communities found in the area. This report represents a concerted effort to relate species feeding and reproductive requirements to the successional stages of plant communities. The habitats required for feeding and reproduction of the various species were compiled and sixteen guilds were formed based on the combination of habitat types used for feeding and reproduction. A classification of community types is developed based on published classification schemes. The published schemes were modified somewhat to more closely fit the fifteen plant communities found in the Blue Mountains.

The data base developed for this system utilized the life requirements of the species to relate to the fifteen community types and the successional stages of the community types. The report contains several levels of analysis of these relationships. The first level of analysis examines the sixteen life forms and displays the number of species within each life form that utilize each plant community and each stage for feeding and reproduction. The analysis allows the determination of how many species or what functions will be affected by development activities affecting a specific plant community. If members of a life form require a successional stage of a plant community for reproductive habitat, and clear cutting or other alteration destroys that stage, a user may determine from this report the approximate number of years it will take for the habitat to reestablish the required successional stage. By identifying the community type and successional stage to be affected by development, the user may then identify the number of species within each life form affected, the number of reproductive or feeding habitats affected, and forecast the number of years which the feeding/reproductive habitat will be affected.

The first level analysis provides information about how the life form may be affected by changes to the plant community. Usually, more detailed information is required. The second level analysis takes each life form and relates the species composing the life form to the plant community and successional stages. In this way the species affected within the life form (rather than simply the total numbers of species) are determined. By identifying the plant community and successional stage affected, one can determine what feeding or reproductive habitats of species are affected, which species may benefit from changes in plant community types, and the suitability of the affected species for the succession stages which replace the affected stage. This enables the user to forecast changes in wildlife species composition by determining how the feeding and reproductive habitats will be affected by management activities.

This report provides brief summary information on each species considered. The summary includes information on distribution, habitats, and other biological attributes. The information includes the importance of each community type for feeding and reproduction, the reproductive capacity and the adaptability of each species. The adaptability or versatility of each species is determined by the number of plant communities and successional stages it can use for feeding and reproduction. For each species considered, a selected reference is included.

3. Applicability:

This report provides a method to use vegetative succession as the basis of assessing changes to wildlife habitat. The plant community type and successional stages of the plant communities are used to determine potential wildlife habitat and how the habitat is affected by management activities which advance or retard succession. The plant community types are based on plant community classifications of forest and range ecosystems (Garrison, 1977) and the vegetation of the U. S. (Kuchler 1964) and may be adapted to other areas within the northwest U. S.

The assumptions, principles, and methods on which this technique is based may be readily used in other areas. Use of the technique in other areas, however, requires development of a similar data base on species use of the different plant community types.

4. Advantages and Disadvantages:

5. Previous Uses:

6. Source/Contact:

Jack W. Thomas, USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, La Grande, Oreg. (503) 963-7122.

1. Name:

U. S. Army Engineer Division, Lower Mississippi Valley, CE. 1980. "A Habitat Evaluation System for Water Resources Planning (HES)," Vicksburg, Miss.

2. Description:

HES is a habitat evaluation system developed to assess aquatic and terrestrial habitat quality in the Lower Mississippi Valley. Habitat quality is based on weighted Habitat Quality Index (HQI) scores of key variables. The HQI scores are measures of quality for key variables such as Species Associations, Percent Inundation, or Distance to Woods, which are considered indicators of habitat quality for a specific habitat type. HES evaluations are thus based on determining the availability, presence or quality of key variables in a study area.

HES documentation sets out the key variables to be considered for two aquatic and four terrestrial habitat types. These are:

Aquatic Ecosystems	Terrestrial Ecosystems
a. Streams	a. Wooded Swamps
b. Lakes	b. Bottomland Hardwood Forest
	c. Upland Forest
	d. Open Lands

For each ecosystem, HES presents the key variables to be evaluated. For example, the key variables evaluated for Lakes are:

a. Total Dissolved Solids.

b. Spring Flooding Index.

c. Mean Depth.

d. Chemical Type.

e. Turbidity.

f. Shoreline Development Index.

g. Total Fish Standing Crop.

h. Sport Fish Standing Crop.

Terrestrial habitat evaluation considers key variables such as follows for the Upland Forest ecosystem:

a. Species Associations.

b. Mast Bearing Trees.

c. Percent Understory.

d. Percent Ground Cover.

e. Large Trees.

f. Tract Size.

g. Number of Snags.

The HQI values are determined through functional relation curves developed for each key variable considered for a habitat. The functional curves relate some characteristic of the variable, such as turbidity units or percent groundcover, to a quality scale. The scale used in HES is 0 to 1.0, with 1.0 being the maximum value or rating attainable by an HQI. The measurement of the key variables is thus transformed into an HQI value. The HQI score is then weighted by a factor to give a weighted HQI score. Weights have been determined for each of the key variables on a 0-100 scale, the sum of the weights for a habitat type being 100. The weighted HQI's for the key variables are summed to give a total HQI for the habitat type. The total HQI is multiplied by the acreage of that habitat type to give a Habitat Unit Value (HUV). The HQI score (total HQI/100) is a 0-1.0 value representing the habitat quality of the habitat type based on the key variables.

Use of HES for impact assessment is accomplished by determining changes in HUV over the life of the project. The projected changes in land use, hydrologic changes, and vegetative succession are used to predict changes in HQI and acreage of habitat. The changes in HUV are annualized to show losses or gains in HUV for the Without Project Plan and each alternative under consideration. The HUV's for all habitat types may be summed to show total changes in habitat quality. Changes in HUV for each habitat type indicate how habitat quality is affected by the alternatives under consideration.

The development of the functional curves, weights, and rationales for key variables is based on the pertinent literature and professional experience of biologists familiar with the ecology of the Lower Mississippi Valley. HES provides for changes in weights, functional curves, or key variables based on the needs of the user.

3. Applicability:

HES provides a method for evaluating the quality of habitats which may be used to describe baseline conditions through development of the HQI scores. The changes in habitat quality are assessed by calculating Annualized Habitat Unit Values for use in the Evaluation of Effects step.

HES may be used in an EQEP analysis to measure habitat quality. In HES, habitat quality is determined by key habitat variables.

Although the functional relationships, weights, and key variables are specific for the Lower Mississippi Valley, the methodology used may be adapted for other areas. Planners within a particular region may draw on their experience and relevant literature to develop viable functional curves, weights, and variables for the habitat types in the area.

4. Advantages and Disadvantages:

The advantages of HES are that it provides a systematic method of quantifying and comparing impacts to dissimilar habitat types through use of a standardized unit, the HQI. The HQI can be compared over time and among habitat types. Adverse and beneficial impacts of the alternatives are identified in comparable terms, the HUV, for impact assessment and for the trade-off analysis in evaluation. The results of HES are reproducible and scientifically defensible in that they are based on the funtional curves, weights, and measurement of key variables developed through professional experience and supported by the literature.

HES provides evaluation of terrestrial habitats using a minimum of field and laboratory data; many of the variable values can be quickly made by visual estimates. Data for most aquatic functional curves can be obtained form historical data sources.

A chief disadvantage of HES in its present form is the specificity to the Lower Mississippi Valley. In addition, the results of HES may not be utilized to project populations or density of a particular species as HES is based on describing habitat quality for a broad range of species.

5. Previous Uses:

HES was developed in 1976 and has been used since that time to evaluate habitat quality within the Lower Mississippi Valley.

6. Source/Contact:

Mr. Tom Holland, FTS 542-5849, (601)634-5849, U. S. Army Engineer Division, Lower Mississippi Valley, Environmental Resources Branch, P. O. Box 80, Vicksburg, Miss. 39180.

1. Name:

U. S. Environmental Protection Agency. 1979. "Methods for Chemical Analysis of Water and Wastes," EPA-600/4-79-020, Environmental Monitoring and Support Laboratory, Cincinnati, Ohio.

2. Description:

This manual was prepared by the Environmental Protection Agency (EPA) to provide the test procedures for monitoring water quality under the Safe Drinking Water Act, the Federal Water Pollution Control Act Amendments (FWPCAA), and the National Pollutant Discharge Elimination System. For each of the water quality parameters included, recommended procedures are explained for determination of the parameter in water samples. In most cases, several candidate procedures are included for each parameter. The list of parameters covered in the manual is included in the Extended Profile Section. Many of the recommended methods are duplicative of the methods included in Standard Methods for Examination of Water and Wastewater. The emphasis in this manual is on instrumental methods because of the improved speed, accuracy, and precision available with these methods.

For each of the techniques presented, the following information is included:

a. Scope and application of the method.

b. Summary of the method.

c. Interferences (e.g., other constituents) to be expected with the method.

d. Sample preservation, handling, and preparation.

e. Equipment, reagents, instruments, required for the method.

f. Procedures to be followed in the method.

g. Calculation of results.

h. Precision and accuracy data on each technique.

3. Applicability:

The methods for water analysis contained in this report provide state-of-the-art techniques for water analysis. Because the methods were identified for compliance with FWPCAA, these methods would be most appropriate in situations where water quality standards for an area are not being met.

4. Advantages and Disadvantages:

The advantages this reference has over other water analysis references are that it provides the most recent documentation on state-of-the-art methods for water analysis. In areas where water quality standards are not being met, the EPA recommended methods for determination are identified.

5. Previous Uses:

6. Source/Contact:

Environmental Monitoring and Support Laboratory, Office of Research and Development, U. S. Environmental Protection Agency, Cincinnati, Ohio 45268.

1. Name:

U. S. Fish and Wildlife Service. 1980. "Habitat Evaluation Procedures (HEP)," ESM 102, Release 2-80, Division of Ecological Services, Fish and Wildlife Service, Washington, D.C.

2. Description:

HEP is a habitat based assessment procedure developed by Fish and Wildlife Service to quantify development impacts on terrestrial and aquatic habitat. Development of HEP has occured over a period of years with changes made to the procedures based on interagency review. The 1980 procedures incorporated a number of changes which cause significant alterations in the data collection and analysis. Two major changes are:

a. Analyses of individual evaluation species, rather than habitat types (cover types) throughout the analysis. Previous versions of the HEP utilized vegetative cover types, e.g., deciduous forest, as the basis of analysis. HEP uses evaluation species or groups as the analysis unit.

b. Determination of the Habitat Suitability Index (HSI) by use of documented habitat model (the HSI is an index which is assumed to be directly related to the carrying capacity for an evaluation species). A guide has been prepared to assist in the development of HSI models. (103 ESM, "Standards for the Development of Habitat Suitability Index Models for Use with the Habitat Evaluation Procedures.")

The HEP analysis is accomplished by determining the habitat quality of an area for a number of evaluation species and projecting how habitat quality will change in the future with and without development. HEP analysis requires measurement of the area of available habitat and the suitability of the habitat for the evaluation species. These two pieces of information are combined to determine the Habitat Units (HU) for a particular species. The area of available habitat is measured in acres or hectares from study area maps or aerial photography. The suitability of the habitat is expressed as the HSI and is scaled from 0 to 1. The HSI can be determined through use of HSI models for the evaluation species or by use of other documented models. The HEP analysis is then implemented using the HSI models for baseline and impact assessments.

The determination of the evaluation species is a critical step in the HEP analysis. It is important that the species selected for evaluation provide a broad ecological perspective of the study area. As stated in 102 ESM, "The degree to which predicted impacts for these species can be extrapolated to a larger segment of the wildlife community depends on careful species selection." Procedures are presented to assist the user in identifying a workable number of evaluation species from the species in a study area. One method is based on the concept of guilding, that is, identifying groups of species with common ecological characteristics. A species from a guild is used to represent all species from the guild and impacts to the guild representative are assumed to be similar for other guild members. The formation of terrestrial guilds is based on feeding and reproductive characteristics. The development of aquatic guilds is more complex and based on the following:

a. Feeding habits.

b. Reproductive habits.

c. Tolerance and response to temperature.

d. Preferred habitat.

e. Tolerance to the results of a potential habitat alteration, such as turbidity-siltation.

For each evaluation species, the habitat type or habitat types required for feeding and reproduction are determined. The relationship of different habitat types, i.e., interspersion, and determination of its importance is assessed. For species needing more than one habitat type for feeding and reproduction, the model must describe how the HU value for the different habitat types are to be aggregated.

The habitat types important to the evaluation species are mapped for the study area maps. Guidelines are presented to assist in determining the number of necessary sampling sites for each habitat type.

After identifying the evaluation species, appropriate HSI models must either be identified in the literature or developed. The HSI model used should produce an index with a proven, quantified relationship to carrying capacity, that is, units of biomass/unit area or units of biomass production/unit area. In addition, the values produced by the HSI model should exhibit linearity, i.e., a change in HSI from 0.1-0.2 is the same magnitude as a change from 0.8-0.9. The calculations and mechanism the HEP analysis uses for comparing proposed actions are based on the assumption of a linear index.

Utilizing the sampling plan, the assessment team conducts the field investigations necessary to collect data for use in the HSI models. The different habitat types are evaluated for the evaluation species which would use the habitat for feeding, reproduction, or cover.

The HSI model is used to calculate the HSI for each sample site for each species. The mean HSI for each species in each cover (habitat) type is calculated. The mean HSI is utilized for development of HU values for the species. The mean HSI is multiplied by the area of habitat and the resulting value is the number of the Habitat Units available for a species. The process just described summarizes the baseline assessment procedures for a HEP analysis.

Using HEP for impact assessment involves determining the changes in HU that occur over the period of life of a proposed project. For the project, a number of target years are identified. The target years represent points in time when the habitat conditions are reasonably well defined and significant changes are expected to occur. The target years may be, for example, preconstruction, construction, and postconstruction or some other point in time. The habitat conditions for each of the target years are projected. The projected habitat conditions are used to develop HU values for each of the target years. The annual change in HUs between target years is calculated and these between years changes are summed yielding the total change in HU over the life of the project. The total change in HU is divided by the economic life of the project to yield the Average Annual Habitat Unit (AAHU). The AAHU for each evaluation species is compared by examining the with-project and without-project AAHU for the species.

Procedures are included to assist the planner in comparing alternatives through a trade-off analysis. The trade-off analysis is accomplished by weighting the AAHUs. The trade-off analysis is considered optional and is not an integral part of the HEP analysis. Its presentation is to explain how value judgments about the evaluation species may be incorporated into a HEP analysis. The weighting factors are called Relative Value Indexes (RVIs) and are developed by rating the evaluation species on a number of RVI criteria. The AAHU for each species is multiplied by the RVI to produce relative AAHU. The relative AAHU represent the combination of value judgments with the HU. The relative AAHUs are no longer directly related to carrying capacity because value judgments have been made. Procedures are presented for development of a compensation analysis using HU as the basis for analysis. As with the trade-off analysis, the compensation analysis, is optional. The basis of the compensation analysis is to identify management measures that would offset losses in HUs. The compensation analysis yields an acreage or area required for compensation or mitigation that, managed for wildlife, would offset the losses in HUs. The use of HUs as the basis of a compensation or mitigation analysis is presented using three different compensation goals or strategies (i.e., in kind, equal replacement, and relative replacement).

3. <u>Applicability</u>:

HEP has been developed to provide a quantified habitat based impact assessment technique. Use of the HSI to measure habitat quality provides a way to assess the long term impacts on habitat through development of HU and AAHU and provide a way to consider changes in habitat types, both changes in quality, through use of HSI models, and changes in quantity, through data on land use changes.

The resources required for a full HEP analysis make it more readily suited for more advanced planning studies. Later stages would have all required data, e.g., detailed project alternatives and aerial photography available.

A modified HEP analyses could be used in earlier planning studies. In the earlier studies, aerial photography and limited field reconnaissance could be used to analyze existing land use, develop HU values for the existing ecosystems, and to begin to identify habitat impacts.

4. Advantages and Disadvantages:

The chief advantage of a HEP analysis is that it is a systematic method to quantify habitat impacts through measurement of changes in fish and wildlife habitat. HEP provides a habitat based assessment technique capable of carrying capacity dealing with changes in habitat types over time.

The disadvantages of using HEP are in some ways similar to the disadvantages of any method requiring coordination and consensus of a number of assessment team members.

5. Previous Uses:

A number of Corps projects utilized earlier versions of the HEP. During FY 80 and 81, four demonstration studies were undertaken to assess the feasibility of using HEP 1980 in Corps planning. The evaluation of use of HEP in the demonstration studies is scheduled for December 1982. The Fish and Wildlife Service applied HEP on approximately 110 studies in FY 1981.

6. Source/Contact:

Team Leader, Western Energy and Land Use Team, Project Impact Evaluation Team, Office of Biological Services, Fish and Wildlife Service, Creekside One, 2625 Redwing Road, Fort Collins, Colo. 80526
(303) 223-2040.

1. Name:

U. S. Fish and Wildlife Service. 1981. "Standards for the Development of Habitat Suitability Index Models," ESM 103, Release 1-81, Division of Ecological Services, Fish and Wildlife Service, Washington, D. C.

2. Description:

This manual provides the guidance necessary for the construction of Habitat Suitability Index (HSI) models. The purpose of the HSI models is to provide a measurement of habitat suitability that may be used in conjunction with measurement of habitat area for use in the Habitat Evaluation Procedures (HEP). A HEP analysis provides a measure of habitat suitability in terms of Habitat Units (HU). The HU's for a study site are calculated as

$$HU = HSI \times Area$$

The HSI is a numerical index that represents the capacity of a given habitat to support a selected fish or wildlife species. The HSI index ranges from 0 to 1.0, 0 being totally unsuitable habitat and 1.0 being optimum habitat. A HSI model and resultant HSI values relate the suitability of the habitat to carrying capacity for the evaluation species included in the HEP analysis. The 0-1.0 index assumes that there is a direct linear relationship between the HSI value and the carrying capacity. This linearity assumption is required so that a unit change in HSI will produce a unit change in carrying capacity.

Existing models for the evaluation species may be used. The conversion of existing models to HSI models requires that the resultant output be a 0-1.0 value. By defining a standard of comparison, existing model output may be converted to HSI. That is,

$$HSI = \frac{\text{Existing Model Output}}{\text{Defined Standard of Comparison}}$$

The type of models which may be converted to HSI are:

a. Word ranking models--e.g., excellent, good, average. Numerical values may be assigned to each rank and the standard of comparison, i.e., the denominator in the above ratio, is equal to the highest numerical value.

b. Models with defined output units--models with output in such units as standing crop, productivity, or density may be utilized. The basic task in using a model such as existing regression model is to define a standard of comparison that corresponds to the maximum regional value for the predicted measure.

c. Models with undefined output units--the output of the model is in the form of a numerical rating or an index. If habitats are ranked from 1 to 5 with 5 being the best available habitat, then 5 is the standard of comparison.

When an existing model is not used, construction of a model focuses on identifying the habitat variables related to the species' carrying capacity and aggregating the variables into a single value. The identification and aggregation of habitat variable data follows a systematic procedure to ensure that the HSI value produced by the model adequately represents the capacity of the habitat to support the evaluation species. The generalized approach for identifying model variables consists of reviewing the literature on the species and selecting those variables that meet the following three criteria:

a. The variable is related to the capacity of the habitat to support the species.

b. There is at least a basic understanding of the relationship of the variable to habitat, e.g., what is the best and worst condition for the variable and how does the variable interact with other variables

c. The variable is practical to measure within the constraints of the model application.

In addition, there are four components used to define habitat variables for an evaluation species:

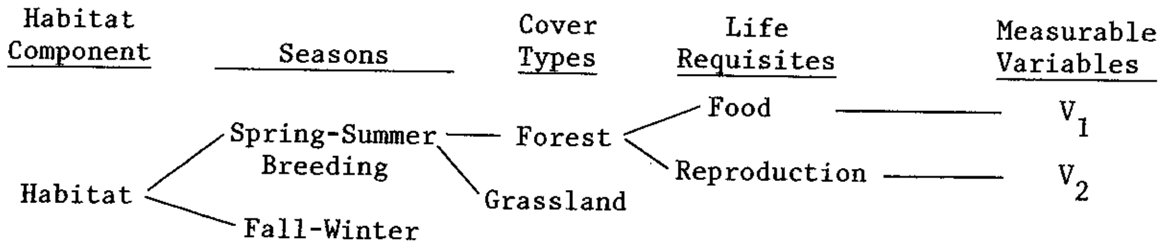
a. Seasonal habitat--habitat used for a particular period during a species' annual life cycle, e.g. winter range

b. Life requisites--the food, cover, water, reproductive, or special resources supplied by a species' habitat. Life requisite components can be separated into categories such as seasonal foods, nesting habitat, or brood-rearing habitat.

c. Life stage--usually utilized for aquatic models and includes egg, larval, fry, juvenile, and adult stages of a species because the life requisite needs for each stage differ.

d. Cover type--cover types are used to define spatial relationships between habitat components. Cover types are used to define habitat suitability based on the spatial relationships (interspersion) of food, cover, and reproductive resources.

The product from examination of the above four components is the identification of measurable habitat variables. This analysis is graphically displayed in the following tree diagrams for a terrestrial example:



In considering the components, if life requisites are identified in more than one cover type, additional variables may be required to relate the life requisites to overall habitat suitability. These additional variables are spatial variables. The spatial variables describe the relationship of cover types "as an indication of life requisite interspersion." The spatial variables should function within the model such that optimum habitat occurs when:

a. All life requisites are of high quality and are in close proximity to one another.

b. The portion of the study area providing a life requisite is at or above some defined level.

After habitat variables are identified, the habitat suitability model is structured. Structuring the model is accomplished by defining the relationship between the variables V_1, V_2, etc. Defining the relationship between variables requires explicating how the variables relate to each other and the significance of the measured variables to habitat suitability. The relationship may be defined by use of a graphical display, written statement, or mathematical equation. The Standards discuss five approaches to establishing model relationships. These are:

A. Word models--a word model is constructed by making sentence statements about the variables or various combinations of the variables. It is desirable that the model assign a significance to a particular measure of the variable. Word models usually relate optimum, medium, and marginal suitability to different levels of the measured variables.

B. Mechanistic model--mechanistic models describe habitat suitability by aggregating suitability index scores from the habitat variables. To do this, first a suitability index for each variable must be developed. The suitability index relates the 0.0-1.0 value to the habitat variable. That is, the 0.0-1.0 scale is related to the units of the variable. This functional relation allows quick translation of a measured variable, such as percent canopy cover, into a measure of habitat suitability, the 0-1.0 index value corresponding to the measured units.

After defining functional relationships for each variable, the relationship between the variables is determined. This means that after an index relationship for each variable is defined, it must be aggregated with the other index values for the next higher level component in the model. The methods of aggregation are as follows:

a. Limiting factor method--this relationship exists when the variable with the lowest suitability overrides other variables in terms of limiting habitat suitability. In effect, the component index is equal to the lowest variable index. This, in effect, makes one variable to be an absolute limiting factor.

b. Cumulative relationships--if the suitability is determined by the additive suitabilities of two or more variables, then the functional relationship is additive or cumulative; the suitability indexes of the variables are summed.

c. Compensatory relationships--when a variable with marginal or low suitability is offset by the high suitability, of other variables, a compensatory relationship exists. Mathematically, this relationship is expressed as an arithmetic mean or a geometric mean of the index values or the variables.

d. Spatial relationships--If the habitat model contains two or more cover types, the aggregation technique must consider interspersion variables. The interspersion variables are:

   (1) Distance between cover types. A suitability index graph is developed for the distance between cover types having the life requisites.

   (2) Percent of the study area composed of each cover type. The percent of a study area composed of each cover type is used to define the proportion of the study area that provides each life requisite. The cover type percent data are combined to calculate percent of the study area providing each life requisite by summing the products of the area of cover type and the suitability index for the life requisite in the cover type. For each life requisite, the sum of products for each cover type is compared to a specified optimum percentage.

C. Pattern recognition models--these models are based on the pattern of answers to a set of questions about the conditions of habitat variables. These questions may take a form such as:

Percent herbaceous canopy
A. Less than (or =) 65 percent
B. Greater than 65 percent

or

Percent of herbaceous canopy between 6 and 40 cm tall
A. Less than (or =) 50 percent
B. Greater than 50 percent

The pattern of answers, e.g., A,A or A,B, for the variable conditions determines the HSI. The assignment of suitability index values to each pattern of answers is determined by expert opinion, based on information from the literature, or is assigned by some other method.

Variables for pattern recognition models can be defined so that they are easy to measure from aerial photography, making this type of model development especially useful in early stages of planning.

D. Baysian probability models--these models provide output in terms of potential population density. The use of Baysian probability models requires the ability to assign conditional probabilities of high or low population densities to the habitat variable measurements. The use of this aggregation technique requires the following:

(1) The range of measured values for each habitat variable is divided into a number of subranges. Each subrange is assigned a probability of having either a high population or a low population density associated with the subrange. Adequate fieldwork is required for correct assignment of these probabilities.

(2) High-density and low-density standards, that is, the highest and lowest long-term population densities of the species found in the geographic unit.

(3) Measured habitat conditions in the study area for each variable.

The above three pieces of information are used to determine the probability of high density, probability of low density, and potential population. For calculation of HSI, the potential population is divided by the high-density standard (standard of comparison).

E. Multivariate statistical models--these models produce estimates of such things as predicted standing crop or biomass based on measurement of the habitat variables which have the greatest influence on standing crop or biomass. (Statistical methods are required to mathematically determine which variables are most strongly related to biomass or standing crop). The two statistical techniques which can be used for HSI construction are:

(1) Regression models--standing crop or biomass of a species is often predictable based upon a set of measurable habitat variables. Regression analysis produces an equation incorporating these variables.

(2) Discriminant analysis models--these models assign a study site to a particular population group based on certain habitat characteristics. The population group categories may range from very high to none. The use of discriminant analysis is based upon the assumption that certain habitat characteristics are unique to each population group and thus can be used to predict whether or not the population in a particular study area is likely to occur within that group.

The use of a discriminant analysis model requires developing a set of discriminant functions for predicting group membership. Discriminant functions are developed by the following steps:

(1) Identifying areas of "known" habitat suitability and assigning them to a suitability group.

(2) Measuring the selected environmental variables in the habitats assigned to a group. A number of easy to use computer programs are available to analyze the data. Analysis of the data produces classification function coefficients for each variable. The coefficients are used with variable measurements to determine the proper group classification for a study site.

In addition to the development if HSI models, the manual also provides guidance for:

a. Setting model objectives. Model objectives include such things as defining acceptable model output and levels of reliability given available time, information, and funding. The setting of model objectives occurs prior to identification of variables and structuring the model.

b. Documentation of the model--information pertaining to the model includes:

(1) General habitat use information for the evaluation species.

(2) Model construction and use. This information is to substantiate the model construction process by identifying the assumptions used and the decisions made during the process. Especially included are decisions about applicability of the model, decisions on the model variables to be used, and the aggregation technique used.

c. Verification of the model--this includes review by the author, analysis with sample data, review by a species authority, and test with field data.

3. Applicability:

This manual has direct applicability for development of habitat suitability models, either for use in a HEP analysis or for evaluation of any evaluation species. The manual provides the necessary procedural guidance for models to be used in an EQEP analysis.

4. Advantages and Disadvantages:

This manual provides a comprehensive procedure, which with the required literature search on each species, can be used to construct habitat suitability models. References are provided for each step and procedure to further assist the user in model development.

5. Previous Uses:

The procedures described in this manual are being utilized to develop models for implementation of HEP. The manual documents the use of its procedures in the development of HSI models for the gray squirrel, red-tailed hawk, and channel catfish.

6. Source/Contact:

Team Leader, Western Energy and Land Use Team, Project Impact Evaluation Team, Office of Biological Services, Fish and Wildlife Service, Creekside One, 2625 Redwing Road, Fort Collins, Colo. 80526 (303) 273-2040.

1. Name:

Vannote, Robin L. et al. 1980. "The River Continuum Concept," Canadian Journal of Fisheries and Aquatic Sciences, Vol 37, No. 1, pp 130-137.

2. Description:

This paper presents what it terms the river continuum concept. This concept states that the structural and functional characteristics of stream communities are adapted to conform to the most probable or mean state of the physical system. This concept is derived from the energy equilibrium theory of fluvial geomorphologists. This concept is utilized to relate stream order, i.e., headwater, medium-sized streams, and large rivers to

a. Ecosystem structure and function.

b. River ecosystem stability.

c. Temporal adjustments in stream community composition.

d. Ecosystem processing along the community.

This concept purports that producer and consumer communities characteristic of a given reach become established in "harmony with the dynamic physical conditions of the channel." As a stream flows from headwater to the mouth, the geomorphological processes of a stream influence energy input, organic matter transport, storage, and use by macroinvertebrate feeding groups. The physical structure coupled with hydrologic cycle form a templet for biological response and result in consistent patterns of community structure and function and (2) organic matter loading, transport, utilization, and storage along the length of a river.

In this analysis, producer and consumer communities characteristic of a given reach of the river continuum conform to the manner in which the river system utilizes its kinetic energy in achieving a dynamic equilibrium. Therefore, over extended river reaches, biological communities should become established which approach equilibrium with the dynamic physical conditions of the channel. The biological analog to the physical model of the system hypothesis that biological organization in rivers "conforms structurally and functionally to kinetic energy dissipation patterns of the physical system." Readjustments are made by the biotic community to any changes in the redistribution of use of kinetic energy by the physical system. The structure and function of stream ecosystems are characterized in terms of productivity and morphological-behavioral adaptations of invertebrates (see Figure 1).

In terms of productivity, headwater streams (orders 1-3) are heterotrophic. These streams are influenced strongly by riparian vegetation which reduces autotrophic production by shading and contributes large amounts of detritus. The Production/Respiration ratios for these streams is less than one (P/R <1) indicating the importance of terrestrial organic input for these streams. The invertebrate communities adapted to this environment are the shredders and collectors which make use of the coarse particulate organic matter (CPOM, >1 mm), such as leaf litter and fine particulate organic matter (FPOM, 50μm-1 mm).

As streams move from headwater areas to medium-sized streams (orders 4-6), production shifts from heterotrophic to autotrophic. This shift is due to increased reliance on algal or rooted vascular plant production. This shift to autotrophic conditions is accompanied by a shift in invertebrates to greater emphasis on grazers or scrapers. These species are adapted primarily for shearing attached algae from surfaces.

Large rivers (stream order >6) utilizes quantities of FPOM from upstream processing of dead leaves and woody debris. The effect of riparian vegetation is insignificant, but primary production may be limited by depth and turbidity; this case P/R >1. The invertebrates of large rivers are dominated by collectors. This is because of a general reduction in detrital particle size and lack of algal and rooted vegetation.

In relating river ecosystem stability to physical stability, ecosystem stability is "achieved by a dynamic balance between forces contributing to stabilization (e.g., debris dam, filter feeders, and other retention devices; nutrient cycling) and those contributing to its instability (e.g., floods, temperature fluctuations, microbial epidemics). The stability of the ecosystem is seen to be the result of physical components, i.e., the physical stability of the stream and biotic components.

In physically stable systems, biotic contributions to ecosystem stability may be limited. However, in widely fluctuating environments (e.g., stream reaches with large fluctuations in temperature) the biota present may assume critical importance in stabilizing the entire system. River ecosystem stability may be related to changes in such factors as riparian influence, substrate flow, and food, as well as temperature.

In considering the example of temperature in a stream which experiences wide diel temperature changes, organisms may be exposed to suboptimum temperatures for significant portions of the day; however, during some portion in the diel cycle, each organism encounters a favorable temperature. Under these conditions, an optimum temperature will occur for a larger number of species than if the thermal regime displayed minimum variance. Thus, an important aspect of a predictably fluctuating physical system is that it encompasses optimum conditions for a large number of species.

Natural stream ecosystems tend toward uniformity of energy flow on an annual basis. Although the processing rates and efficiencies of energy utilization are believed to approach equilibrium for the years, the major organic substrates shift seasonally. There is a seasonal shift in the relative importance of autotrophic production versus detritus loading and processing. The detritus inflow is important in supporting autumn-winter foodchains and providing a fine particle base for consumer organisms during other seasons of the year. During the spring and summer months, autotrophic communities often form the major food base. This shift in food bases assists in maintaining an equilibrium of energy flow.

In addition to the shift in food bases, it has been observed in headwater streams that a temporal sequence of syncronized species replacement occurs. As a species completes its growth in a particular microhabitat it is replaced by other species performing essentially the same function, differing principally by the season of growth. It is this continuous species replacement that functions to distribute the utilization of energy inputs over time. The biological system moves towards equilibrium by a trade-off between a tendency to make the most efficient use of energy inputs through resource partitioning of food, substrate, temperature, and a tendency toward a uniform rate of energy processing throughout the year. The authors conclude that energy flow strategies observed on small- to medium-sized streams (orders 1-5), propose that biological communities developed in natural streams in dyanmic equilibrium assume processing strategies involving minimum energy loss.

The dynamic equilibrium resulting from maximization of energy utilization and minimization of variation in its use over the year determines the storage and leadage of energy. Unused or partially processed materials will be transported downstream. This energy loss is the energy income with local inputs for communities in downstream reaches. The authors contend that downstream communities are structured to capitalize on the inefficiencies of upstream processing. Communities distributed along the river are structured to process the materials delivered (specific detrital sizes algae and vascular hydrophytes) therby minimizing the variance in system structure and function. THus, the minimization of the variance of energy flow is the outcome of seasonal variation of energy input rates (detritus and autotrophic production) coupled with adjustments in species diversity, specialization for food processing, temporal expression of functional groups, and the erosional-depositional transport and storage characteristics of flowing waters.

As a correlation to the continuum hypothesis, the authors further put forth the concept that biological systems established in a dynamically balanced physical setting can be viewed in a time independent fashion. This concept, time in variance, allows integration of community structure and function along the river without concern for successional stages. The authors contend that the "concept of biological succession is of little use for river continuance because the communities in each reach have a continuous heritage rather than an isolated temporal composition within a sequence of discrete successional states." The biological subsystems for each reach are in equilibrium with the physical system at that point in the continuum. This concept implies that in natural river systems total absence of a population is rate and biological subsystems are simply shifting spatially and not in the temporal sense typical of plant succession.

3. Applicability:

The river continuum concept may be utilized to analyze changes in the stream ecosystem within a study area. The concept was developed with reference to natural, undisturbed stream ecosystems. Utilizing this concept it is possible to characterize a stream ecosystem as it exists and to anticipate changes due to proposed alternatives. Using the developed model, ecosystem changes could be predicted which alter the relative degree of autotrophy: heterotrophy (e.g., nutrient enrichment, organic pollution, alteration of riparian vegetation, or clear-cutting) or actions which affect the quality and quantity of transport (e.g., impoundment, high sediment, or detrital load). These alterations can be thought of as mechanisms which cause the overall continuum response to be shifted to the headwaters or seaward depending on the type of pertubation and its location on the river system.

Regarding an EQEP analysis, the river continuum concept provides a framework for analyzing a significant river ecosystem. By determining the stream order and the extent to which the ecosystem is stabilized it is possible to predict changes that will occur in the ecosystem by delineating pertubations caused by various alternatives under consideration.

4. Advantages and Disadvantages:

The advantages of utilizing the river continuum concept ensue from the fact that it is a holistic approach to river ecosystem assessment integrating predictable and observable biological features of aquatic systems with the physical-geomorphic environment. This model provides the framework for determining ecosystem response to proposed alterations to the aquatic or riparian environment.

A disadvantage of using the continuum concept is that projected impacts may be understood qualitatively, but an adequate understanding of specific response strategies, e.g., differential metabolic responses, to fully describe and quantify impacts is lacking.

5. Previous Uses:

Applications of the river continuum concept are not documented in this article.

6. Source/Contact:

Dr. Robin L. Vannote, Academy of Natural Sciences of Philadelphia, Avondale, Pennsylvania.

1. Name:

Wang, Flora C., Odum, Howard T. and Lehman, Melvin E. 1977. "Concepts and Techniques for Evaluation of Energy-Related Water Problems," Center for Wetlands, University of Florida, Gainesville, Fla.

2. Description:

This report describes the most comprehensive technique identified which uses energy as the basis for assessment. The technique combines state-of-the-art knowledge on energy analysis with regionally determined data on energy use. In assessing a natural system, it is always critical to consider the utilization and transformation of energy within the system. However, due to the pervasive nature of energy flow, from solar to primary production and use at higher levels, an energy analysis for a region or even an ecosystem quickly becomes complex.

This report reviews state-of-the-art methods for energy analysis. The energy flow through a system is analyzed through development of energy quality factors. These factors equate different types of energy, e.g., sunlight, on the basis of coal equivalents (CE). These factors represent the ratio of low quality inflow energy to high quality outflow energy, e.g., electricity. The higher quality energies, such as electricity, have better ability to perform work. The CE conversion factors represent the energy cost of the processes necessary to convert one form of energy into another. Using these factors, the energy in terms of sunlight may be determined from the amount of electricity or other energy source used.

In addition to the energy quality factors, the energy amplifier effect and water and water flow are viewed as limiting factors in the evaluation. The energy quality of water is its gravitational and chemical potential. The energy quality of water is thus related to its gravitational position and its chemical potential as a reactant. Equations for potential gravitational energy and chemical potenital energy yield values for calories per gram of water and Cal/acre-foot to be used in the analysis.

The methods for energy analysis of natural systems were reviewed. These methods all use energy flow diagrams which track the flow of energy between the economic and environmental sectors. Because of the relationship between land use and energy flow, it is impossible to separate the flow of energy. The use of water in the industrial and agricultural sectors results in the addition of fossil fuel and the investment of money. These inflows of energy are considered in the energy analysis.

This report describes the allocation of land use on the basis of utilization of energy. The allocation was based on the maximum power principle. This principle states that systems which maximize their flows of energy survive in competition. "Maximizing the economy involves maximizing the power flow of the combined system of man and nature, which, in turn, means utilization of energies in a design with high quality energy used to amplify the lower quality energies to form closed loops webs both in nature and in the economy." Thus, this energy analysis is based on maximization of useful power. (The energy units used are coal equivalents throughout the study.)

This study used a linear programming model to allocate land use within a county on the basis of energy use. Land use is allocated among four sectors: urban, industrial, agricultural, and natural or undisturbed. The linear programming model was formulated to maximize the utilization of energy in the sectors. Allocation of land use was based on energy utilization by the sectors given constraints of the availability of water resources, land acreage, fuel resources, solar insulation, and pollutant restrictions. The objective function takes the form: Maximize $C_A X_A + C_N X_N + C_I X_I + C_U I_U$, where X_A, X_N, X_I, and X_U are the acreages of agricultural, natural, industrial, and urban land sectors, and C_A, C_N, C_I, and C_U are coefficients that represent the total useful energy production per unit of land.

A computer program designed for linear programming was used to solve the objective functions (See Source/Contact below). The data required for the program include the energy values from inputs of solar energy and fossil fuel energy (in CE Cal/ac), and the energy value of water and land (in CE Cal/ac). These values were determined in studies which developed an input-output analysis for the region, a hydrologic budget model for the area, and an energy based agriculture study of the region. These studies had been done prior to the linear programming effort. The energy values developed in these studies were used as the a_{xz} and C_y coefficients in the objective and constraint functions.

Using the energy values, a first run of the computer program is accomplished. This first run allocates land use to the agricultural, natural, industrial, and urban uses. The program allocated land to maximize the energy utilization. By maximizing the objective function, land use is allocated so that energy utilization is maximized. Maximization is indicated as useful work generated in Cal or CE.

The development of the constraint functions allows a sensitivity analysis to be performed by modifying the constraints. In this way, successive computer runs show changes in allocation of land resulting from changes in the availability of water, fossil fuels, water resources, and the variance of pullution control standards. In this way, the effects of changes in resource availability on energy utilization is determined.

3. Applicability:

This technique is included because it provides an analysis based on energy flow. The maximization of energy may be used on a regional (as in this case) or at the ecosystem level. In either case, if the data required for the analysis are extensive. It is desirable to consider energy flow from an ecological standpoint because of its centrality to ecological production. The energy analysis techniques used in this study are state-of-the-art methods.

4. Advantages and Disadvantages:

The advantage of using an energy analysis similar to that described in this report is that the analysis is an assessment based on ecologic functions, the flow of energy, its transformation, and flow between subsystems.

The disadvantage is that, to be used competently, the analysis requires development of an adequate input-output model and other quantitative energy-based data.

5. Previous Uses:

This energy analysis method was used to allocated land in Lee County, Florida.

6. Source/Contact:

Reference - Computer program - IBM, 1971. MPSX - Multiple Programming System Extended, Control Language User's Manual, Program Number S-734.XM4, International Business Machines, Inc., First Edition.

1. Name:

Whitaker, Gene A. and McCuen, Richard H. 1975. "A Proposed Methodology for Assessing the Quality of Wildlife Habitat", Technical Report, Department of Civil Engineering, University of Maryland, College Park, Maryland.

2. Description:

This paper describes a technique to measure habitat quality through development of a model (computerized though simple enough to be used without computer assistance). This habitat quality technique is similar in methodology to the Habitat Evaluation Procedures (HEP), but the data requirements and the model used are less complex. The methodology was developed to assess the change in habitat quality for a watershed in western Maryland.

The paper describes various models used for habitat quality purposes and points out that additive models may fail to account for the interactive nature of the model components. For this reason, a weighted geometric mean model is developed. This model structure was believed to be a realistic alternative to the additive models because it accounts for interaction between components and because the degree of interaction can be controlled by the weights given to each component.

The model developed for the Maryland application considered three components for wildlife habitat:

a. The degree of interspersion of land use.

b. The quantity of each land use.

c. The management or vegetative condition.

For each of these components, a transformation curve or transformation table was developed to relate the component to a quality scale of 0 to 1.0. This technique considers two types of wildlife species in the planning area, categorized as woodland and openland wildlife. The species in the categories were considered to have similar requirements for feeding and reproductive habitat.

The openland wildlife included species that are normally found in cropland, meadows, and areas of nonforested land overgrown with grasses and shrubby growth. They are generally dependent on edge but derive most of their substance from openland. Examples of openland wildlife for this technique were quail, rabbits, meadowlarks, sparrows, robins, skunks, and meadow mice. Woodlife wildlife are those birds and mammals commonly found in wooded areas. Although many of the species utilize open areas, especially herbaceous cover, most of their needs are found in wooded areas. Among these species are the white-tailed deer, ruffed grouse, squirrels, turkey, raccoon, thrushes, vireos, and deer mice. The following type of land use found in the watershed were evaluated:

a. Cropland.

b. Herbaceous cover.

c. Woodland.

d. Residential areas.

e. Water areas.

For the woodland and openland wildlife, transformation curves were developed that related the percentage of each type land use to a 0-1.0 scale. The exact form of each land use curve is dependent on the ability of the land use type to provide suitable habitat for the wildlife. The percentages of land use were determined through mapping from aerial photography. Curves are thus developed for each habitat (land use) type for both the woodland and openland wildlife.

The transformation curves for the interspersion category considered the importance of the different habitat types and how the distance between the types affected the quality of the habitat. The mean distance in feet for the following interspersion distances were related to the 0 to 1.0 scale.

Openland Wildlife

a. Cropland to woody cover.

b. Cropland to herbaceous cover.

c. Herbaceous to woody cover.

d. Woodland to openland.

Woodland Wildlife

a. Openland to woody cover.

b. Woodland to cropland.

c. Woodland to herbaceous cover.

d. Woodland to water areas.

e. Woodland to residential areas.

The mean distances were calculated using the mapped cover types.

The evaluation of the management condition of the habitat types relates the land use management practices to a wildlife value factor, not a functional (continuous) relationship. For instance, for the cropland habitat type, the condition corn-grain harvested, no tillage, was assigned a factor of 1.0 for open-land wildlife and 0.8 for woodland wildlife.

After development of the transformation curves and factors, a sampling plan is used to identify sampling sites. The sites are evaluated for the three categories. Prior to use of the model, weights must be developed. A weight is assigned to indicate the importance of management, interspersion, and land use quantity to reflect the relative importance of the categories to the wildlife species or group of species under consideration. The wildlife requirements are the basis for development of the weights. For example, for openland wildlife, "generally recognized as creatures of edge, the degree of interspersion of land uses may be considered most important and thus given the largest weight".

The formula used in the model produces a factor based on the measurements of interspersion, management, and land use quantities for each habitat type under the three categories. The factors produced by the model represent the quality of the habitat. The factor is multiplied by the total acreage to represent habitat quality. This value is called the acre value unit. Future conditions in land use changes may be used to develop projections of impacts. The change in acre values may then be compared to judge impact of various alternatives.

3. Applicability:

The technique described above is a method to assess habitat quality through use of an interactive model. This technique, while producing results similar to HEP is not nearly as complex. The model is limited to those habitat variables which interact and also may be readily determined from aerial photography and limited field work. The use of only two wildlife groups or guilds decreases the data requirements. The use of this technique relies heavily on professional experience with the area being evaluated for development of the transformation values and weights. However, similar level of professional experience may be required to implement a more complex technique, such as HEP.

4. Advantages and Disadvantages:

5. Previous Uses:

This technique was used to assess the impacts to a Maryland watershed (57,289 acres).

6. Source/Contact:

EXTENDED PROFILES SECTION-

EQEP TECHNIQUES

American Public Health Association. 1976. Standard Methods for the Examination of Water and Wastewater, Fourteenth Edition, Washington, DC.

Water parameters included in the text.

Physical Examination

- Appearance
- Calcium Carbonate Saturation
- Color
- Conductivity
- Odor
- Oxygen Transfer
- Residue
- Salinity
- Specific Gravity
- Taste
- Temperature
- Turbidity

Metals

- Aluminum
- Barium
- Beryllium
- Cadmium
- Calcium
- Chromium
- Copper
- Hardness
- Iron
- Lead
- Lithium
- Magnesium
- Manganese
- Mercury
- Nickel
- Potassium
- Selenium
- Silver
- Sodium
- Strontium
- Vanadium
- Zinc

Inorganic,Nonmetallics

- Acidity
- Alkalinity
- Arsenic

Boron
Bromide
Carbon Dioxide
Chloride
Chlorine
Chlorine Demand
Cyanide
Fluoride
Iodide
Iodine
Nitrogen
Oxygen
Ozone
pH Value
Phosphate
Silica
Sulfate
Sulfide
Sulfite

Organics

Grease and Oil
Methane
Organic Acids and Volatile Acids
Organic Carbon
Organic Contaminants
Oxygen Demand - Biological
Oxygen Demand - Chemical
Pesticides
Phenols
Sludge Digester Gas
Surfactacts
Tannin and Lignin

Automated Laboratory Analysis

Chloride Ferricyanide Method
Fluoride Complexone Method
Nitrogen Phenate Method
Nitrogen Cadmium Reduction Method
Phosphate Ascorbic Acid Reduction Method
Sulfate Methylthmol Blue Method

Radioactivity - Water and Wastewater

Radioactivity in Wastewater
Srontium in Water
Radium in Water
Radium 226 by Radon in Water
Tritium in Water

Bioassay Methods for Aquatic Organisms

Biostimulation - Algal Productivity
Phytoplankton
Zooplankton
Scleractinion Coral
Marine Polychaete Annelius
Crustaceans
Aquatic Insects
Mollusks
Fishes

Microbial Examination

Coliform Group
Fecal Streptococcal Group
Pathogenic Microorganisms
Enteric Viruses
Examination of Recreational Waters
Fungi
Actinomycetes
Nematodes
Iron and Sulfur Bacteria

Biological Examination

Plankton
Periphyton
Macrophyton
Benthic Macroinvertebrates
Fishes

Hayes, Robert L. 1981. "Estimating Wildlife Habitat Variables," FWS/OBS-81/47, Western Energy and Land Use Team, Fish and Wildlife Service, Ft. Collins, Colo. (Prepared by Colorado Cooperative Wildlife Research Unit, Colorado State University, Ft. Collins, Colo.)

Category: Properties of Individual Plants

a. Basal area

b. Canopy area

c. Canopy diameter

d. Plant height

e. Stem diameter

f. Vertical projection of a point to the ground

Category: Properties of Vegetation, Litter, and the Soil Surface

"Homogeneous" properties of sites

a. Cover

Basal cover

Canopy cover

Foliar cover

b. Density

c. Frequency

d. Height

e. Litter depth

f. Horizontal foliar density

g. Species diversity, evenness component

Site Dimensions and Intersite Juxtaposition (Interspersion)

a. Distance to

b. Edge length per unit area

c. Patton's Diversity Index

d. Site area

e. Site linear dimensions

Category: Landform Characteristics

a. Slope

b. Aspect

Category: Soil Characteristics

Soil texture

Category: Aquatic System Characteristics

a. Width of water body

b. Water depth

c. Surface water velocity

The techniques described in the handbook include the following:

a. Calculated area of a plant

b. Crown diameter

c. Diameter tape

d. Merritt hypsometer

e. Christen hypsometer

f. Trigonometric hyposometry

g. Graduated rod

h. Optical rangefinder

i. Biltmore stick

j. Lindsey sighting level

k. Vertical rod

l. Line intercept

m. Bitterlich method

n. Calculated cover

o. Point intercept - step point

p. Point intercept - pin frame

q. Point intercept - spherical densiometer

r. Point intercept - canopy camera

s. Ocular estimation of cover

t. T-square nearest neighbor sampling

u. Quadrat

v. Averaging

w. Vegetation profile board

x. Calculated community dominance

y. Map measurer

z. Pacing

aa. Line intercept measurement of edge/area

bb. Calculated edge/area

cc. Patton's diversity index

dd. Point grid

ee. Slope and aspect from topographic maps

ff. Clinometer and compass

gg. Soil texture

hh. Floating body

Table 1. Aesthetic Factors, Categories, and Evaluation Criteria.

Factor No.	Descriptive categories	Evaluation numbers of descriptive categories 1	2	3	4	5
	Physical factors:					
1	River width at low flow ft	<3	3 to 10	10 to 30	30 to 100	>100.
2	Depth at low flow ft	<.5	.5 to 1	1 to 2	2 to 5	>5.
3	Velocity at low flow ft	<.5	.5 to 1	1 to 2	3 to 5	>5.
4	Bankfull depth ft	<.1	.1 to 2	2 to 4	4 to 8	>8.
5	Flow variability	Little variation	Little variation	Normal	Ephemeral or large variation.	Ephemeral or large variation.
6	River pattern	Torrent	Pool and riffle	Without riffles	Meander	Braided.
7	Ratio of valley height to width.	≧1	2 to 5	5 to 10	11 to 14	≦15.
8	Bed material mm	Clay or silt	Sand	Mixture of sand and gravel.	Gravel	Cobbles or larger.
9	Bed slope ft per ft	<.0005	.0005 to .001	.001 to .005	.005 to .01	>.01.
10	Basin area sq mi	<1	1 to 10	10 to 100	100 to 1,000	>1,000.
11	Stream order	≧2	3	4	5	≦6.
12	Erosion of banks	Stable	—	Slumping	—	Eroding.
13	Deposition	Stable	—	—	—	Large-scale deposition.
14	Width of valley flat ft	<100	100 to 300	300 to 500	500 to 1,000	>1,000.
	Biologic and water quality:					
15	Water color	Clear and colorless.	—	Green tints	—	Brown.
16	Turbidity mg/l	<25	25 to 150	150 to 1,000	1,000 to 5,000	>5,000.
17	Floating material	None	Vegetation	Foamy	Oily	Variety.
18	Water condition	Poor	—	Good	—	Excellent.
	Algae:					
19	Amount	Absent	—	—	—	Infested.
20	Type	Green on rocks	Blue green	Diatom	Floating green	None.
	Larger plants:					
21	Amount	Absent	—	—	—	Infested.
22	Kind	None	Unknown rooted	Elodea and duckweed.	Water lily	Cattail.
23	River fauna	None	—	—	—	Large variety.
24	Pollution evidence	None	—	—	—	Evident.
	Land flora:					
25	Valley	Open	Open with grass and trees.	Brushy	Wooded	Trees and brush.
26	Hillslope	Open	Open with grass and trees.	Brushy	Wooded	Trees and brush.
27	Diversity	Small	—	—	—	Great.
28	Condition	Good	—	—	—	Overused.
	Human use and interest:					
	Number of occurences of trash and litter per 100 ft of river:					
29	Metal	<2	2 to 5	5 to 10	10 to 50	>50.
30	Paper	<2	2 to 5	5 to 10	10 to 50	>50.
31	Other	<2	2 to 5	5 to 10	10 to 50	>50.
32	Material removable	Easily removed	—	—	—	Difficult.
33	Artificial controls	Free and natural	—	—	—	Controlled.
	Accessibility:					
34	Individual	Wilderness	—	—	—	Urban or paved access.
35	Mass use	Wilderness	—	—	—	Urban or paved access.
36	Local scene	Diverse views and scenes.	—	—	—	Closed or without diversity.
37	Vistas	Vistas of far places.	—	—	—	Closed or no vistas.
38	View confinement	Open or no obstructions.	—	—	—	Closed by hills, cliffs, or trees.
39	Land use	Wilderness	Grazed	Lumbering	Forest and mixed recreation.	Urbanized.
40	Utilities	Scene unobstructed by power or electric lines.	—	—	—	Scene obstructed by utilities.
41	Degree of change	Original.	—	—	—	Materially altered.
42	Recovery potential	Natural recovery	—	—	—	Natural change unlikely.
43	Urbanization	No buildings	—	—	—	Many houses and buildings.
44	Special views	None	—	—	—	Unusual interest.
45	Historic features	None	—	—	—	Many.
46	Misfits	None	—	—	—	Many.

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Table 2. Summary-Totals of Uniqueness Ratios of Aesthetic Factor Values.

Site	Aesthetic factors			Total
	Physical	Biologic	Human interest	
1	3.06	2.92	5.09	11.07
2	3.73	2.66	4.61	11.00
3	3.53	2.81	5.53	11.87
4	4.69	5.15	4.09	13.93
5	3.20	4.41	8.48	16.09
6	3.75	3.67	3.75	11.17
7	8.88	9.74	4.48	23.10
8	3.26	4.24	6.28	13.78
9	3.28	2.65	4.32	10.25
10	3.80	3.96	7.05	14.81
11	3.43	3.06	5.46	11.95
12	2.84	3.70	3.67	10.21

Table 3. Sites in Order of Uniqueness Ratio.

Rank	Aesthetic factors			Total
	Physical	Biologic	Human interest	
1	7	7	5	7
2	4	4	10	5
3	6	5	8	10
4	2	8	3	4
5	3	10	11	8
6	11	12	1	11
7	10	6	2	6
8	9	11	7	3
9	8	1	9	12
10	5	3	4	1
11	1	2	6	2
12	12	9	12	9

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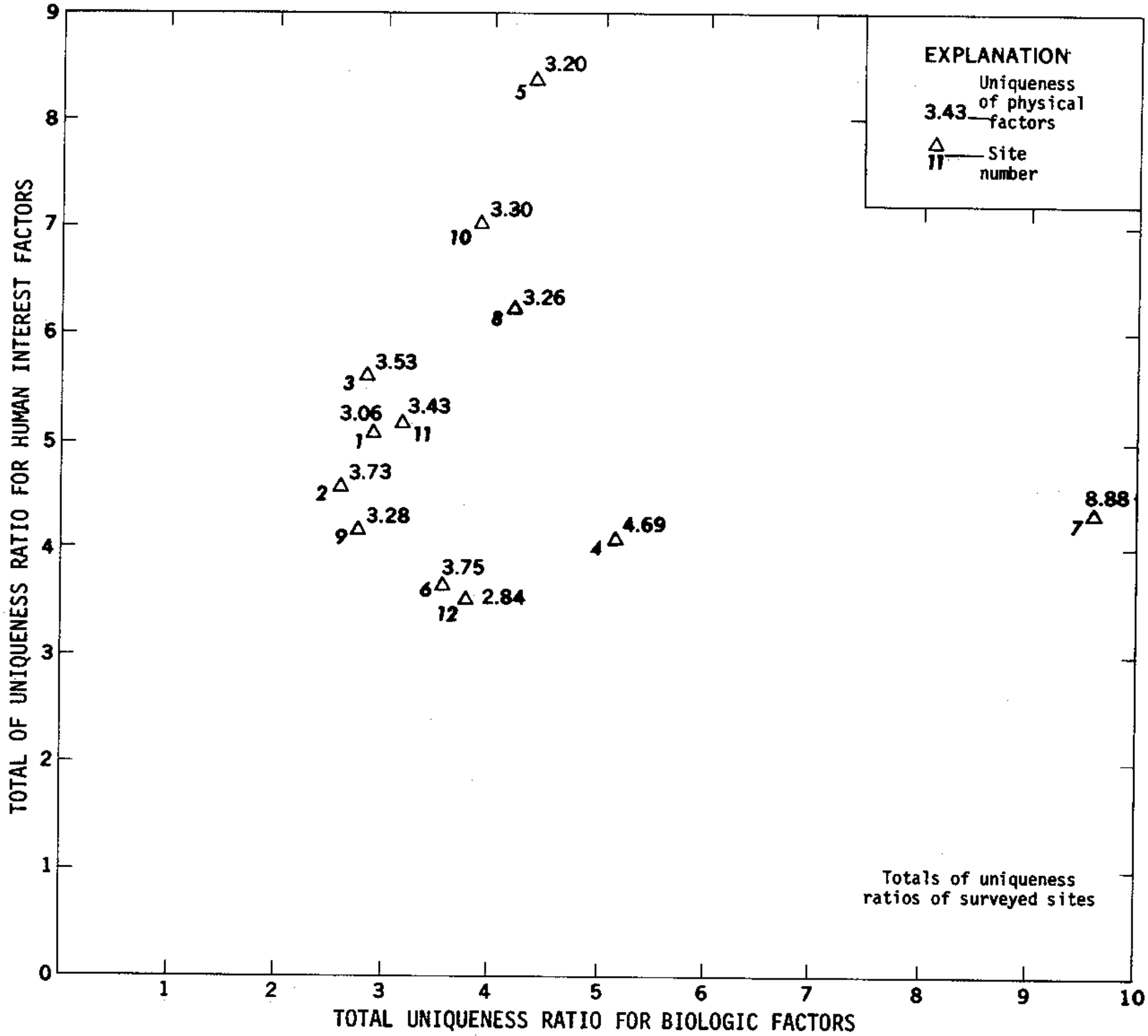
Figure 1. Relatio Among Uniqueness Ratios
of the Groups of Factors



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Water Quality Parameters Included in the Manual

Physical Properties

Color
Conductance
Hardness
Odor
pH
Residue
Temperature
Turbidity

Metals

Aluminum
Antimony
Arsenic
Barium
Beryllium
Boron
Cadmium
Calcium
Chromium
Cobalt
Copper
Gold
Iridium
Iron
Lead
Magnesium
Manganese
Mercury
Molyberm
Nickel
Osmium
Palladium
Platinum
Rhenium
Rhodium
Ruthenium
Selemium
Silver
Sodium

Metals (Continued)

Thallium
Tin
Titanium
Vanadium
Zinc

Inorganic, Nonmetallics

Acidity
Alkalinity
Bromide
Chloride
Chlorine
Cyanide
Fluoride
Iodide
Nitrogen
Nitrate
Nitrate-Nitrite
Nitrate
Oxygen, Dissolved
Phosphorus
Silica, Dissolved
Sulfate
Sulfide
Sulfite

Organics

Biochemical Oxygen Demand
Chemical Oxygen Demand
Oil and Grease
Organic Carbon
Petroleum Hydrocarbons
Phenolics
Methylene Blue Active
Substances
NTA (Zinc)

APPENDIX C: BIBLIOGRAPHY

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In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Henderson, Jim E.
  Handbook of environmental quality measurement and assessment: Methods and techniques / by Jim E. Henderson (Environmental Laboratory, U.S. Army Engineer Waterways Experiment Station). -- Vicksburg, Miss. : The Station ; Springfield, Va. : available from NTIS, 1982.
  350 p. in various pagings ; ill. ; 27 cm. -- (Instruction report ; E-82-2)
  Cover title.
  "May 1982."
  Final report.
  "Prepared for Office, Chief of Engineers, U.S. Army under EWQOS Task IVA (Work Unit 31607).
  At head of title: "Environmental & Water Quality Operational Studies."
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